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ABSTRACT

This report focuses primarily on the technological dimensions of competitiveness in the United States with its capability to: create and effectively use technology; increase the value added to goods and services through the application of technology; manage technology in industry for more effective relationships among companies, universities, and the government in the creation and use of technology; and develop a motivated work force capable of adapting to a technologically dynamic workplace. The roles and performance of industrial, governmental, and educational institutions involved in and responsible for the generation and application of technology for commercial purposes are discussed, and proposals for action are offered. The coda of the committee is provided along with committee membership. (MVL)

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The Technological Dimensions of International Competitiveness

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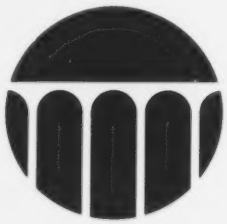

The Technological Dimensions of International Competitiveness

Prepared by the Committee on
Technology Issues that Impact
International Competitiveness

Washington, D.C. 1988

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Robert M. White is president of the National Academy of Engineering.

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Preface

In recent years the issue of national competitiveness, the ability of U.S. industry to compete in global markets, has become a central concern both for policymakers in industry and government and for individuals. The ability of the United States to maintain or increase the standard of living of U.S. citizens in the face of increasing global economic competition is a multifaceted problem. It is affected by a wide array of factors, including monetary and fiscal policies, industrial practices, the structure and behavior of financial markets, social norms and expectations, and technological capabilities.

Technological advance plays a central role both in changing the environment of competition and in providing firms with a capability to excel in their products and processes. This report focuses on the role of technology and engineering in improving U.S. competitiveness and offers some important ideas, drawn from the engineering world, for the directions needed to improve competitiveness. In particular, the themes of quality and continuous improvement in actions, policies, and organizations are recognized in this report as central to achieving national competitiveness.

Opportunities for improvement in the technological aspects of U.S. competitiveness do not exist solely within the domain of any one institution: industry, government, and academia all share responsibility for more effective creation and use of technology in the U.S. economy. In short, improvements in U.S. competitiveness cannot be achieved by any quick, single action or by any one sector of society acting alone. This observation holds true whether the opportunity and necessary action call for improving the effectiveness of governmental regulatory procedures, strengthening the capability of U.S. producers to commercialize new technologies, increasing the efficacy of industry-university R&D relationships, or rationalizing the role of the U.S. government in bridging the gap between scientific discovery and commercialization. This report describes many actions required of industry, government, and educational institutions.

To probe the technological dimensions of the competitiveness issue, the National Academy of Engineering convened a committee of its members drawn from industry, government, and academia. The committee was charged with a broad examination of the issue of technology and competitiveness, being as comprehensive as possible while synethesizing the large amount of available information about what is obviously a complex and controversial topic. The committee focused on the application of technology in industrial settings, on strengthening the support of research and development for commercial purposes, and on selected issues in education. The committee did not explicitly explore the role of basic research in the support of technological development but proceeded on the assumption that the United States must maintain a vigorous effort in basic research to maintain its world leadership in science as the long-term underpinning of its economic growth.

In reaching its judgments, the committee drew heavily on the wealth of analyses and reports on competitiveness, including recent efforts by the National Academy of Engineering and the National Research Council. A number of the topics addressed have been widely debated in other forums, in particular the appropriate role of government in supporting research upstream from commercial applications but significantly downstream from basic research. Although committee members held divergent views on this topic, there was agreement on the need for a careful reexamination and rationalization of the government's role.

The committee, cochaired by W. Dale Compton and George E. Solomon, deserves the special thanks of the National Academy of Engineering for its efforts on behalf of this project. The committee was supported by the NAE Program Office, and thanks are due to James H. Schulman, consultant to the project; Bruce Guile, associate director of the Program Office; H. Dale Langford, NAE editor; and Mary Jay Ball, administrative secretary.

Robert M. White
President

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Summary

A nation's competitiveness is the degree to which it can produce goods and services that meet the test of international markets while simultaneously maintaining or expanding the real incomes of its citizens. This national capability is affected by a wide array of national and international economic conditions, government policies, societal norms, industrial practices, and technological developments.

This report, while acknowledging the complexity and diversity of factors affecting competitiveness, focuses primarily on the technological dimensions of competitiveness—the capability of the United States to create and effectively use technology, to increase the value added to goods and services through the application of technology, to manage technology in industry, to form more effective relationships among companies, universities, and the government in the creation and use of technology, and to develop a motivated work force capable of adapting to a technologically dynamic workplace.

The roles and performance of institutions— industry, government, and educational institutions —involved in, and responsible for, the generation and application of technology for commercial purposes are discussed, and proposals for action are offered.

Summary

Industry

In the United States the design, development, production, and marketing of goods and services for world markets are carried out by private businesses. Consequently, U.S. industry—particularly U.S.-based production—bears a responsibility for constant improvement of its effectiveness in creating and bringing products to market. Although individual businesses must choose strategies and tactics that fit specific competitive conditions, a commitment to good engineering practice—the careful attention to function, processes, and materials—is often the primary means for improving the quality and cost of a product or service. Developing consistent and mutually supportive **technical and business strategies** is increasingly critical to the long-term success of a company.

■ **U.S. industry must commit itself to offering world-class products and services at competitive costs. The committee urges U.S. industry to embrace the concept of a *product realization process*, the importance of strong *employee involvement*, and a commitment to *continuous improvement*.**

(See pages 27 through 30 for a discussion of industry's role in U.S. competitiveness and a definition of terms.)

Government

A wide range of government policies, procedures, and regulations critically influences the behavior and performance of industry. This report addresses both the effect of government economic and regulatory policies on the competitiveness of U.S. industry and the role of government support of the R&D enterprise related to industry and commerce. With regard to economic and regulatory policies, the committee concludes that balance must be maintained between the goals of regulations and agency actions and the nation's economic competitiveness.

The dynamic nature of economic, political, and technological developments requires that government policies be constantly reviewed and adapted to ensure that they not only achieve the desired social, political, and national security purposes, but also support—or at least do not impair—our international competitiveness.

With regard to government support of the national R&D enterprise, the changing character of global economic competition justifies a careful reassessment of the role of the federal government in supporting technical activities related to the civilian sector. In particular, the globalization of markets, cooperation among foreign producers to reduce their technology development costs, and foreign government support

Summary

of foreign firms have changed the competitive environment for U.S. firms.

There are, in the committee's judgment, a number of emerging roles for government that could, if successfully implemented, enhance U.S. competitiveness: government policies that stimulate industry to create new products and improve productivity; government actions that permit and even support industry-wide consortia for the joint development of production technology; government contributions to the early development of innovative technologies ultimately intended for the commercial sector; and changes in the role of the federally supported laboratories.

Movement in a useful direction with regard to these new challenges for government requires several actions.

■ **Mechanisms should be developed that encourage government and industry to work together more effectively to anticipate technological challenges.**

■ **The federal government must use its diverse capabilities to broadly encourage the technological developments that are critical to sustaining the competitive interests of the nation. Efforts need to be focused through a designated entity that can effectively respond to industry initiatives and interact with nongovernment groups, including industry.**

■ **To ensure access to the proper information and analytic capability, the government should foster the creation of a supporting activity that, with private-sector participation, could provide high quality, in-depth analyses of the factors affecting the ability of civilian industrial sectors to compete in global markets.**

If government is to develop an expanded role in support of R&D related to industry and commerce, it must rationalize its efforts and focus them in a consistent and logical fashion. The committee recognizes that recommendations regarding new government roles in technological activities downstream from basic research raise a number of unresolved concerns about implementation and the prerogatives of both the private and the public sectors. Readers are encouraged, therefore, to consult the full text of the report (*especially pages 31 through 46*) to understand both the logic leading to the recommendations and the qualifying statements the committee felt must accompany the recommendations.

State governments also play an important role, in part because they have capabilities and attitudes that are not easily duplicated at the federal level; state governments are generally more aware of, and responsive to, the needs of local industry, making it easier for them to interact with small business and experiment with innovative, specialized programs than for the federal government.

■ **State governments should**

- **strengthen and expand their local industrial base through the development and dissemination of technology and know-how that can be effectively used by small businesses to improve their productivity,**
- **continue to support the initiation of high-tech small businesses,**
- **strive to create a favorable environment for all business operations, and**
- **seek to improve the quality of the education systems within their boundaries.**

(See pages 47 through 49 for a discussion of the role of state governments.)

Summary

Education System

To be illiterate in a technologically dependent society is to be trapped. Literacy is a prerequisite of entry into most positions in both the manufacturing and the service sectors, and advancement and upward mobility almost always require strong basic skills in language and mathematics. **Quality in education is every bit as important to the United States as is quality in products, services, or government.** A national strategy is needed that will intensify current efforts to improve public education at primary and secondary levels. A key ingredient in accomplishing this is the establishment of firm and realistic objectives to guide continuous improvement of school programs.

Ensuring an adequate future supply of engineers and scientists, particularly the number of women and minorities who choose science and engineering as a profession, is a recent concern. Since the supply is determined, in no small way, by early educational experiences in mathematics and science courses, primary and secondary school systems should establish objectives for improving the quality of the mathematics and science programs and for developing opportunities for students to understand more completely the nature of a technical career. Improvement in precollege mathematics and science programs is critically dependent on the availability of competent teachers. School systems can retain good mathematics and science teachers only if increased effort is made to provide salaries and benefits that are competitive with other sources of employment and if the working conditions are improved so that teachers can experience increased professional recognition and development *(see pages 55 through 58)*.

The U.S. system of higher education ranks among the best in the world in providing both undergraduate and graduate students with an enriching educational experience. The recognition that many technical areas are increasing in importance to industry, and the growing interest of students in exploring areas that relate to the needs of industry, have stimulated many colleges and universities to experiment with new ways of offering students an opportunity to study and to develop special skills. **Resources need to be provided to colleges and universities to encourage experimentation and establishment of new programs and curricula that will lead to improved industrial competitiveness. Government and industry must share in providing the necessary resources.**

One measure of the high regard in which the U.S. system of higher education is held is the large number of foreign nationals that come to the United States to study and to do research. While there is some concern with the high fraction of foreign-national students in U.S. graduate engineering programs, and with the number of foreign-born faculty members in entry-level positions in engineering schools, the committee believes that the appropriate focus of concern should be the small and declining proportion of U.S. citizens who are choosing to undertake studies for advanced degrees in engineering.

■ **The federal government should develop an incentive program to encourage more United States citizens to pursue advanced technical degrees in fields that are increasingly dominated by non-U.S. citizens.**

Not only are fewer U.S. citizens entering the technical labor force, but present immigration laws reduce the opportunity for U.S. firms to employ the foreign nationals who have been trained in, and have graduated from, U.S. colleges and universities.

■ **Consideration should be given to modifying existing laws and regulations that prevent retention of U.S.-educated foreign nationals with advanced degrees in science and engineering.** This human resource, educated in U.S. schools, should be available to U.S. employers *(see pages 61 through 63)*.

Summary

Universities have recently become involved in efforts to apply technology developed in their laboratories to solve problems important to industry. This trend has led to the creation of a variety of new alliances between industry and universities. These alliances reflect the changing role of universities in national economic development and may have broad implications for the health of the universities.

■ **The implications of new alliances between industry and academe can be best explored by undertaking a study of**

□ **how U.S. colleges and universities are affected by their activities in various aspects of the commercialization of products and processes, and**

□ **the means by which technical understanding and developments are transferred to industry.**

The study should explore various means of improving the capabilities of universities to participate in aspects of the commercialization process and should examine actions that might be taken to improve the effectiveness of the transfer of technology to industry without compromising the primary functions of universities in research and teaching. *(See pages 50 through 53 for a discussion of issues surrounding higher education.)*

It has become increasingly clear that lifelong learning is critical if U.S. citizens are to cope effectively with the complexities and rapid changes of modern society. Career-long educational needs of the work force are extraordinarily diverse and pose many problems for the worker, employer, and education system. Since career-long education is an increasingly important element in maintaining the viability of the work force, a major challenge is to ensure that American industry create an environment that will stimulate personal career and intellectual growth.

■ **The long-range need for a capable and adaptive work force requires that continuing education become an integral part of the career development of each individual, particularly of every scientist and engineer. Industry, government, professional societies, and educational institutions share the responsibility for creating a system that will be of high quality and will encourage the employee and the employer to invest in obtaining skills of future value both to the individual and to industry.** *(See pages 64 through 67 for a discussion of continuing education.)*

Coda

The committee is hopeful that readers will recognize and endorse a pervading theme of this report—the concept of continuous improvement. **Continuous improvement—in education and research, in product development and improvement, in process improvement, in government, and in blending the mutually supportive strengths of all national institutions—is critical to U.S. welfare and to the maintenance of a strong competitive position in a modern global economy.**

Introduction 1

Competitiveness is the degree to which a nation can, under free and fair market conditions, produce goods and services that meet the test of international markets while simultaneously maintaining or expanding the real incomes of its citizens.

President's Commission on Industrial Competitiveness, January 1985

Can products and services produced in the United States compete successfully in the world marketplace? Should one view the large U.S. trade deficit, the domination by overseas manufacturers of major markets for technologically advanced products, and the fact that many commonplace consumer products are now manufactured overseas as important indicators of fundamental changes in the capability of U.S. industry to compete? Do shifts in employment among various sectors of the economy indicate that the United States is in danger of losing the ability to continue to provide meaningful employment to large segments of the population? These are but a few of the questions that are at the heart of concerns about national competitiveness.

The overall economic environment—real interest rates, inflation, prevailing wage rates—is critical in determining whether a firm can improve its productivity, create new products and services, and compete in world markets with U.S.-produced goods and services. Macroeconomic, fiscal, trade, and regulatory policies are critical determinants of this environment.

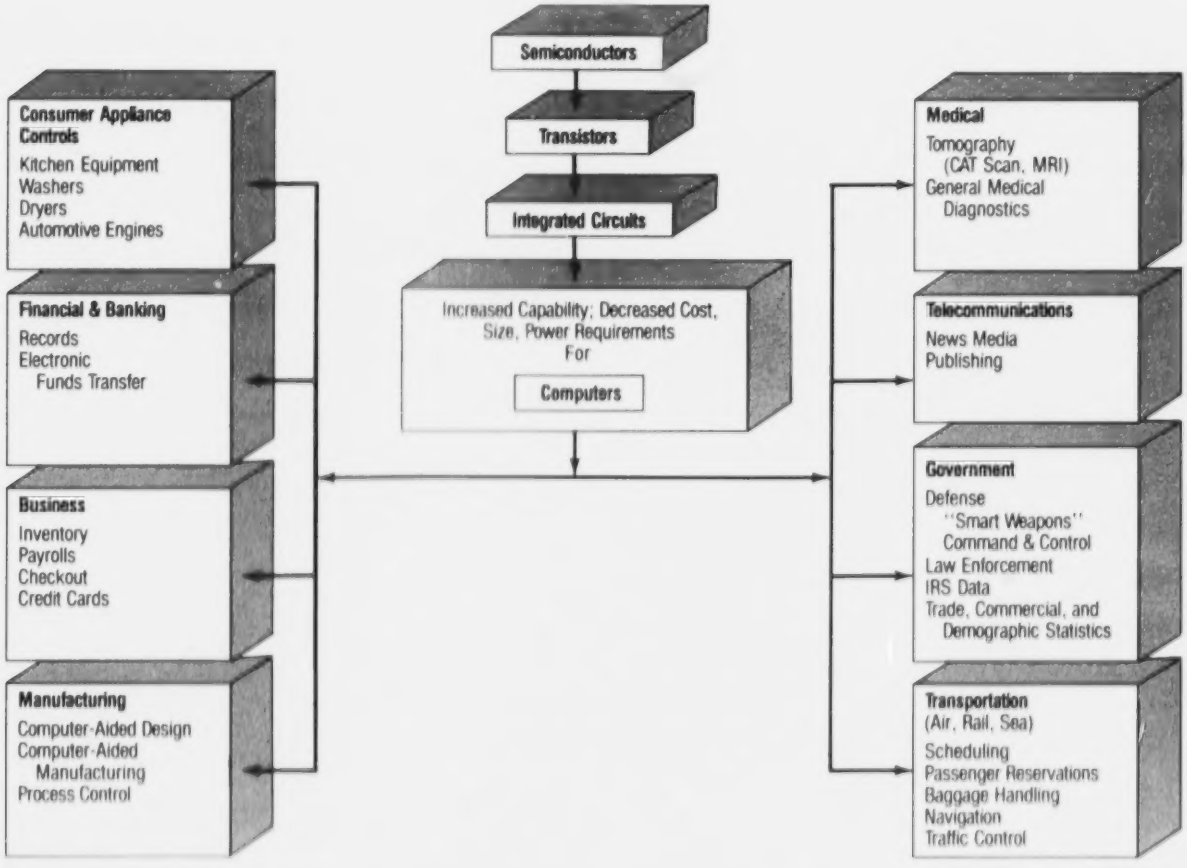
Each firm must, of course, fashion a strategy that recognizes the special character of its business situation, the influence of the general economic environment, and the opportunities and constraints of technology. This is especially important because government policies may affect each firm, industry, and sector differently. Capital-intensive industries will be strongly affected by macroeconomic policies affecting the cost and availability of capital, and policies such as depreciation schedules and investment tax credits. Those industries that invest heavily in R&D will be concerned with R&D tax credits and the treatment of R&D investments and expenses. Some industries will be more heavily influenced by export controls; others will be concerned with the stability of exchange rates or with the protection of intellectual property rights.

If by research and development, new production methods are generated, then the economic growth can continue. . . . The conclusion is then that in the long run, technological development is the major factor behind economic growth.

Source: 1

Introduction

To an increasing degree, businesses are recognizing that a successful competitive strategy includes the effective use of technology. Many opportunities exist for incorporating new technologies into products and processes. New materials, communication technology, and production technology are advancing rapidly. Each can have a pervasive impact on products and processes that are central to our competitiveness. Furthermore, developments in one field can have profound effects on another. For example, hardly a business exists today that is not influenced in some way by the computer, which depends on the technologies of the semiconductor.



The impact of technology on economic development: new processes, products, and services.

Introduction

This report is intended to contribute to the discussion of U.S. competitiveness in the world marketplace. The basic premises of the report—the foundations on which the analysis and recommendations are built—are that the U.S. economy is increasingly dominated by global forces and that the standard of living of U.S. citizens will be increasingly determined by the ability of U.S. industry to compete in the world marketplace.

While acknowledging the broad character of national competitiveness, the report does not attempt to analyze or discuss all of the factors that determine our national competitiveness. Rather, it concentrates on those issues that relate to the creation and effective use of technology in providing new and improved products and services and on the factors that contribute to the ability of firms to increase the value added to products and services produced in the United States. It is concerned with business practices related to the management of technology and the effective use of engineering in improving products and services, with the formation of more effective relationships among companies, universities, and the government, with the development of a more capable and motivated work force, and with government policies that influence the efficiency of those institutions that develop and use technology.

Although science and technology are of critical importance in maintaining and improving U.S. competitiveness, it must be emphasized at the outset that improved national competitiveness cannot be achieved by any quick, single action or by technological means alone. Moreover, no single sector of American society acting alone can reestablish U.S. competitiveness. Improving the performance of U.S.-based production in world markets is a matter of continuous, concerted action by all—business, labor, government, and the education community. This holds true whether the necessary action is improving manufacturing processes and manufactured products, strengthening the ability of U.S. producers to commercialize new technologies, improving the efficiency of governmental operations, increasing the effectiveness of the U.S. education system, or developing an incentive system that encourages long-term savings and investments.

The challenge that America faces is to create an awareness of the urgency for action and the need to marshal the necessary resources. As a nation, we have responded with vigor to perceived threats to national security, public health, safety, and the environment. We are now confronted by a serious threat of another kind—a threat created not by any malevolent force from another nation but by the changing character of economic competition that has developed among the trading nations of the world. This challenge is dynamic. To meet it will demand continuous improvement in our businesses and public institutions at a rate that exceeds that of our principal competitors. If we fail, we face the prospect of stagnation or decline of the American standard of living. The findings and conclusions presented in this report address the strategic technological responses necessary to meet this challenge.

The Changing World Marketplace

2

As Europe and Japan recovered from the devastation of World War II, and as various historically poor nations such as Taiwan, Korea, and Brazil developed their economies, it was reasonable and inevitable that the United States should feel the effect of their competition. Since 1950 real U.S. gross domestic product (GDP) has tripled, real world GDP has quadrupled, and world trade has grown sevenfold.

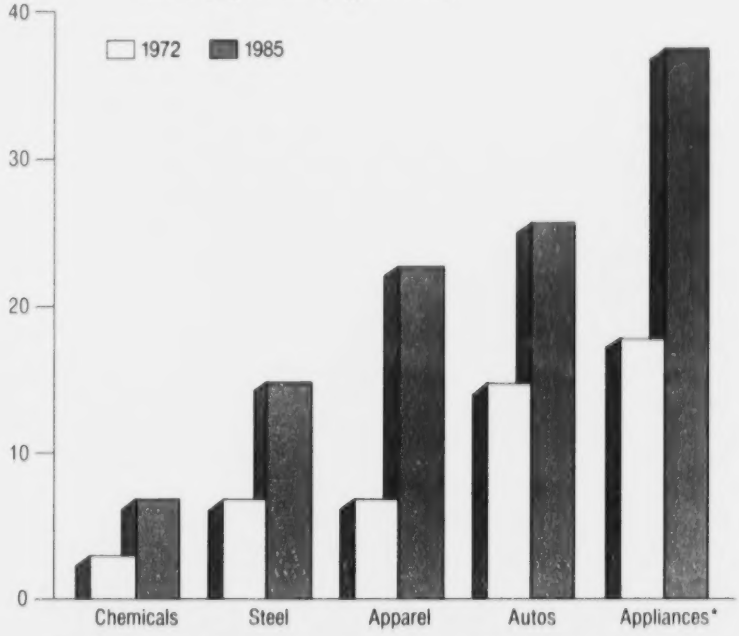
The growing importance of trade in the world economy is reflected in the increasing merchandise imports and exports of the United States and its principal trading partners. Today U.S. merchandise imports and exports, excluding petroleum, are about 35 percent and 25 percent, respectively, of U.S. manufacturing production. Key industrial sectors have been dramatically affected by the increase in imports. It is estimated that about 70 percent of current U.S. manufacturing output faces direct foreign competition.

Merchandise Imports and Exports as a Percentage of National Gross Domestic Product

	1960		1986	
Country	Imports	Exports	Imports	Exports
France	8.6	11.4	17.3	17.2
Japan	8.7	9.4	9.1*	13.3*
Federal Republic of Germany	13.0	15.8	20.2	27.1
United Kingdom	16.3	14.7	21.7	19.6
Canada	14.6	14.4	23.0	24.7
United States	2.9	4.0	9.5	5.2

*1985 Data

Source: 2 Sources of data for this table and subsequent tables appear on pages 71–73.

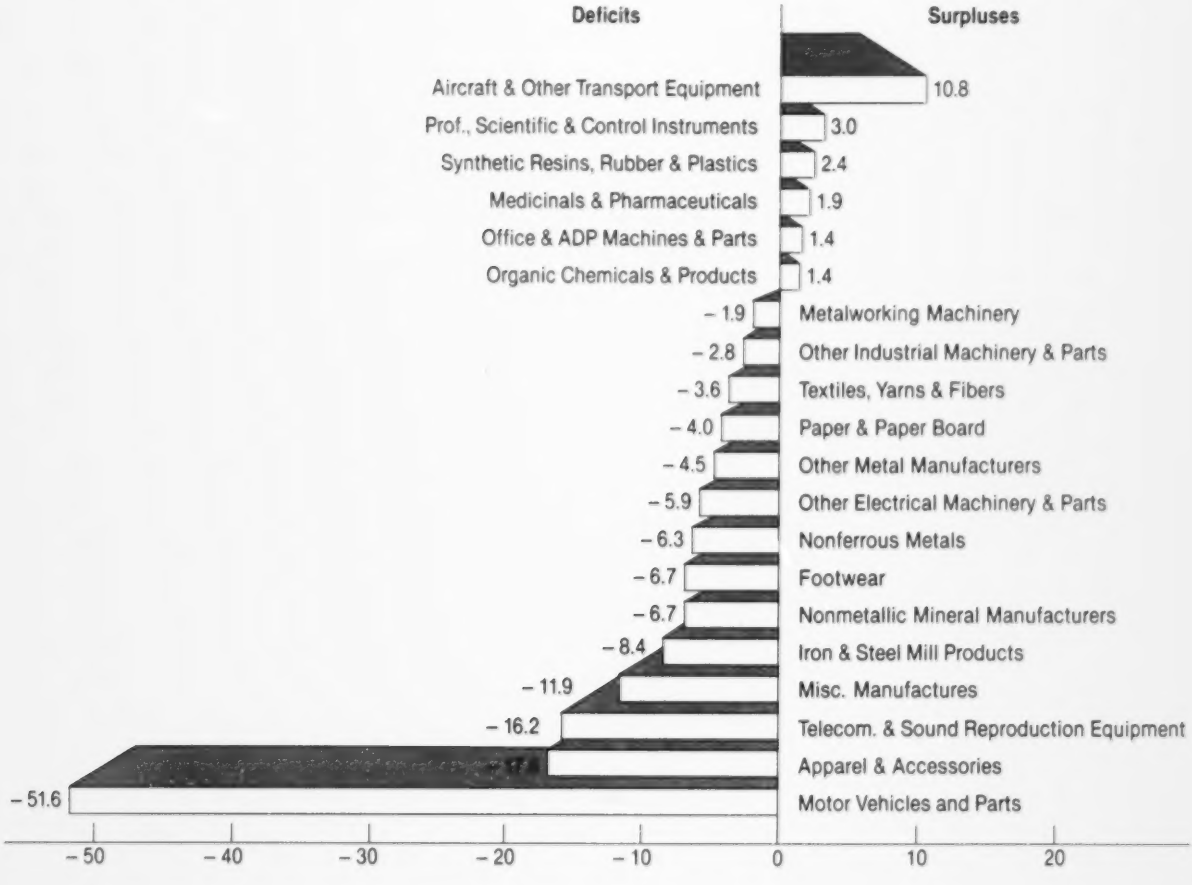


Imports as a percentage of sales in the United States for some major industries, 1972 and 1985.
***Note: Includes domestic appliances, radio and TV sets.**

Source: 3

The Changing World Marketplace

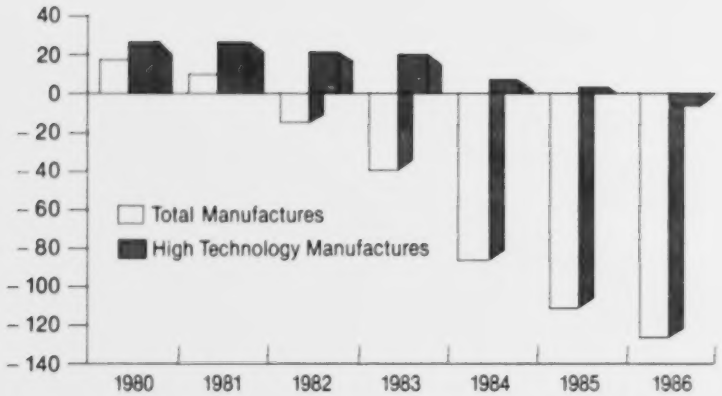
Although U.S. consumers and businesses have benefited from expanded international trade, there is now widespread concern that the magnitude of the inroads into U.S. domestic markets signals a decline in the ability of U.S. producers to compete in global markets. The U.S. merchandise trade deficit reached $130 billion in 1986. Motor vehicles contributed the most to the manufactures trade imbalance. Aircraft exports continued to make a significant positive contribution to the trade balance, but their net contribution declined from $11.2 billion in 1985 to $10.8 billion in 1986.



U.S. manufactures trade balances, by commodity groups, 1986, in billions of dollars.

Source: 4

The Changing World Marketplace



U.S. merchandise trade balance in total and high-technology manufactures, in billions of dollars.
Source: 6

Not only has there been an erosion in old-line industries, but now some of the newer and most technologically advanced U.S. industries—high-technology manufactures, including, semiconductors, telecommunications equipment, computers, and pharmaceuticals, for example—are being severely challenged by international competition. Unfavorable trends in this broad range of industries have reinforced concern that the United States is losing ground in the world economy.

U.S. industries such as automobiles and steel are clearly passing through a period of dramatic change. The machine tool industry, the footwear industry, the textile and apparel industries—industries that have historically been important in the U.S. economy—have lost market share both domestically and internationally to firms based in other nations. Although improvements in cost and quality of U.S.-manufactured products are being achieved, foreign producers continue to maintain a significant share of the U.S. market. It has become evident to both the managers of, and the workers in, many U.S. industries that the challenges from overseas manufacturers are the result not of a cyclical downturn but of a fundamental restructuring of manufacturing activity in the world economy. Employment trends over the past decade in selected U.S. manufacturing industries dramatically demonstrate the impact of the changes that have taken place.

Employment Trends in U.S. Industries Severely Affected by Imports (annual average employment, in thousands)

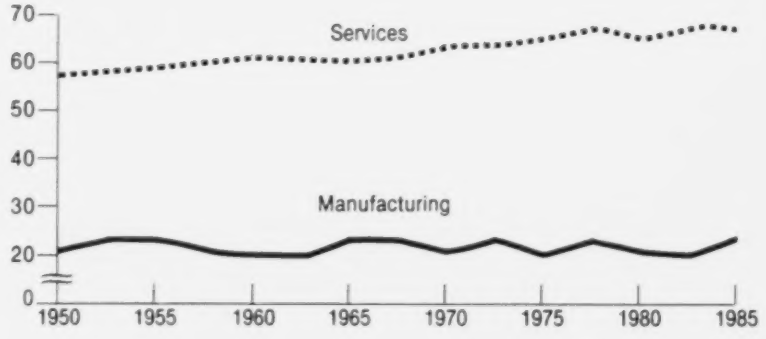
Industry (SIC)*	1976	1978	1980	1982	1984	1986
Textile Mill Products (22)	919	899	848	749	746	705
Blast furnaces/basic steel products (331)	549	560	512	396	334	275
Apparel (23)	1,318	1,332	1,264	1,161	1,185	1,105
Metal-cutting machine tools (354)	62	71	82	65	55	49
Household appliances (363)	170	185	163	139	147	135
Motor vehicles and equipment (371)	881	1,005	789	699	862	865

*Standard Industrial Classification System

Source: 5

The Changing World Marketplace

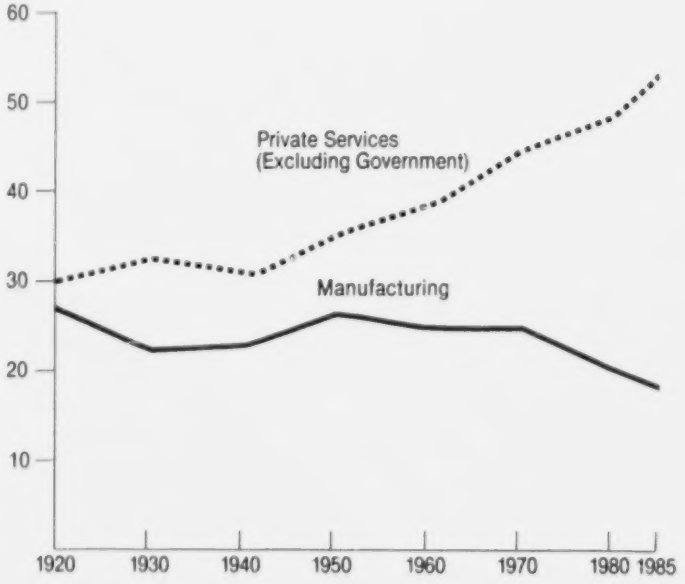
The large merchandise trade deficit that the United States has experienced over the past few years has given many Americans a picture of American manufacturing on the ropes; people seem to have an intuitive sense that U.S. manufacturing is withering under the pressure of more efficient and lower cost competition abroad while employment grows only in low-wage service industries. That view is not accurate. Despite serious inroads made by imports in some sectors, there is still a strong demand for the output of the domestic manufacturing sector. Between 1950 and 1986 the contribution of the manufacturing sector to U.S. GNP—measured in constant dollars—has fluctuated modestly around 22 percent.



Relative shares of GNP by service and manufacturing sectors, constant 1982 dollars.

Source: 7

Although the manufacturing sector's contribution to GNP is fairly constant, employment in the U.S. manufacturing sector has been dropping as a percentage of total U.S. employment. Associated with this decrease has been an increase in employment in the service sector, both in absolute terms and in relation to total employment. This is not a new phenomenon, nor is it localized to the United States. Similar trends, although somewhat less dramatic, are occurring in other developed countries. The upward shift in the percentage of employment in services in the United States became significant in the 1940s. The common belief that this shift in employment reflects wholly a shift from high-wage factory work to low-wage



Manufacturing and private services as a percentage of total employment, 1920-1985.

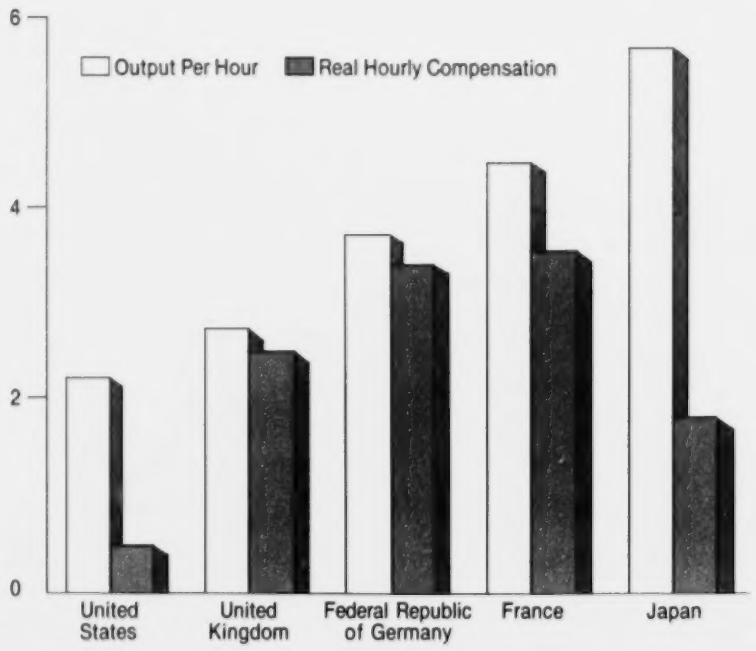
Source: 8

work, as in retail and food services, is belied by a simple examination of the areas in which employment has grown. Although it is true that there has been significant employment growth in retail trade, there has also been substantial growth in several high-technology and relatively high-wage service sectors, such as business services, finance, and health services.

An important determinant of U.S. competitiveness is the productivity of both manufacturing and service industries. U.S. productivity in manufacturing, measured in output per labor hour, is still high in absolute value but has been falling relative to our principal competitors. Between 1973 and 1985, **productivity improvements** in U.S. manufacturing, measured in output per hour and real hourly compensation, were less than those achieved by Japan, France, the Federal Republic of Germany, or the United Kingdom. If the significant improvement in productivity that has been achieved in manufacturing in recent years can be sustained, some of these unfavorable trends can be reversed.

Historically, the productivity growth in service industries as a group has been poor even though some individual service industries, such as communications, have been among the nation's best performers. Additionally troubling is the fact that, although growth in services productivity was similar to that in manufacturing during the late 1970s and early 1980s, service industries have not matched the recent resurgence of productivity growth in manufacturing. Therefore, a primary opportunity for improving total U.S. economic growth currently remains in improving the productivity growth in services.

In summary, an increased exposure to foreign competition, combined with the realities of improving productivity in other nations, has intensified the competition for U.S.-based producers. Both domestic and overseas markets are being challenged by overseas producers. The nation's response to this challenge will critically affect every aspect of our economic system.



Average annual percentage change in manufacturing productivity and real wages in selected countries between 1973 and 1985.

Source: 9

Response To The Global Challenge

3

Concerted action by foreign-based companies, often with a measure of support from their governments, has created a challenge that demands an aggressive response by the United States. In dealing with this challenge, the United States must turn to its principal institutions—government, industry, and the education system—and ensure that they are capable of making an appropriate response.

We begin by restating the obvious—that it is industry that designs, develops, produces, and markets goods and services for world markets. Government and universities are becoming more involved, however, in shaping the way industry discharges these tasks. Our purpose here is to examine the changes taking place in all three institutions and to suggest actions that will enhance their effectiveness in responding to the global challenge.

Response To The Global Challenge

The Role of Industry

The globalization of markets provides customers in industrialized nations with the opportunity to choose from an ever-widening variety of goods and services—many of which are designed and created by firms throughout the world. To an increasing degree, producers can appeal to the particular interests of a customer by offering a product or service that provides the most desirable combination of attributes, including some combination of quality, durability, cost, reliability of supply, and style. The supplier who can provide superior products or services at the lowest cost with the proper mixture of attributes for the broadest spectrum of customers will be the most successful.

The importance of the various attributes that customers consider in making a purchase is strongly product-dependent. Consumers place high priority on ▶ trouble-free performance for automobiles and home entertainment systems. For large and small appliances, durability closely follows trouble-free performance in importance. Design and style are the most desirable attributes for apparel, and price is significant for both apparel and small appliances. For commodity products used by a manufacturer, quality, cost, and reliability of delivery are generally considered critical. For many services, quality, timeliness of response, and cost are important attributes.

Executives' Perceptions of the Role of Quality in Strengthening American Business

Question: What role does quality play in strengthening the ability of U.S. business to compete with foreign competition?

Response	Total %	Larger Companies %	Smaller Companies %	Service Companies %	Industrial Companies %
Very important/high role	80	83	78	81	80
American products inferior to foreign products	15	13	18	15	15
Quality plus price important factors	6	6	6	5	9
Importance of productivity and quality	4	7	2	4	6
Fairly important	3	3	2	2	4
Other	6	5	9	7	5
Total	114*	117*	115*	114*	119*
Number of interviews	(615)	(307)	(308)	(389)	(226)

*Total exceeds 100 percent because of multiple responses.

Source: 11

Consumer Ratings of Important Attributes of Various Products

Most Important Attribute	Product: Automobiles %	Large Appliances %	Home Entertainment %	Small Appliances %	Clothing %
Trouble-free performance	60	55	60	42	NA
Lasts a long time	32	42	30	36	32
Manufacturer's reputation	5	5	7	5	7
Design and style	5	2	4	4	49
Price	5	3	4	15	17
Other	—	—	—	1	—
No answer	—	—	1	1	1
Total*	107	107	106	104	106
Number of interviews	(1,005)	(1,005)	(1,005)	(1,005)	(1,005)

*Totals exceed 100 percent because of multiple responses.

Source: 10

Response To The Global Challenge

The perception that quality can be important in achieving competitiveness is reflected in the high marks that 600 executive officers of U.S. companies gave to quality in response to the question "What role does quality play in strengthening the ability of U.S. business to compete with foreign competition?"

In the same way that the importance of particular attributes varies among products, the source of foreign competitive advantage varies among industries. For example:

☐ The U.S. steel industry has been faced with greatly reduced revenues and negative cash flows because of world overcapacity at a time when large capital investment is needed to modernize plants and facilities.

☐ The U.S. automobile industry was threatened and is still challenged by Japanese producers whose manufacturing practices are often more efficient and whose products are of high quality, and by new manufacturers in less developed nations that have the further advantage of extremely low-cost labor.

☐ The U.S. pharmaceutical industry is challenged in most developing and Third World markets by producers who, often with the sanction of their national governments, do not respect intellectual property rights.

☐ The U.S. commercial aircraft industry is challenged in world markets by foreign producers who receive massive design, development, and production subsidies and whose governments have used various means to assist the development and market penetration of their new aircraft industry.

☐ The U.S. banking industry is disadvantaged in some world capital markets largely because of a structure that evolved under U.S. domestic regulations that were designed to meet problems of the 1920s.

Response To The Global Challenge

In short, the attributes for consumer acceptance and the parameters of international competition are different in different industries. Although the particular responses that can be offered by any U.S. industry to the challenges of the world marketplace must be tailored to the specific competitive situation in the industry and relevant markets, two elements of competitive performance are of nearly universal importance:

- ☐ The competitive advantage belongs to the company that provides the customer with a product or service that has a value—as determined by its cost, performance, and quality—that is better than that of its competition.

- ☐ The competitive advantage accrues to the firm that can respond most effectively and rapidly to changing customer needs and demands—indeed, even to create innovative alternatives to anticipate their demands.

To ignore these key elements of competitive performance is to invite disaster. There are many examples of unfortunate consequences for companies that failed to recognize the value that customers place on quality, ignored the importance of constantly improving the efficiency of production, were unable to respond rapidly to a changing socioeconomic environment as reflected in the marketplace, or did not use their human and capital resources as effectively as their competitors.

As each company seeks to respond to these challenges, it must increasingly be concerned with the manner in which it creates its products, processes, and services. It must also be concerned with the management of the total enterprise, from the development of the initial product concept to the servicing of the product in the field, and with the effective use of technology in creating competitive advantages across the entire spectrum of its business activities. **Industry's response must focus on improving its effectiveness in creating and bringing its products and services to the world marketplace.**

Response To The Global Challenge

Actions by Industry

Rapid and efficient commercial embodiment of an idea in a product or service is an essential element of successful international competition. There are two aspects of this competition: the creation of new or innovative products or services; and the progressive, incremental improvement of an existing product or service.

A firm that is first to offer a new product or first to use an innovative new process has an obvious potential advantage over its competitors. Many innovative products and processes arise from scientific discoveries, and the United States has long been a leader in creating the scientific and technical developments that are the basis of new industries. Microelectronics, optoelectronics, and computers, for example, have developed so fast that they already resemble mature industries, and biotechnology now seems poised for an explosive expansion.

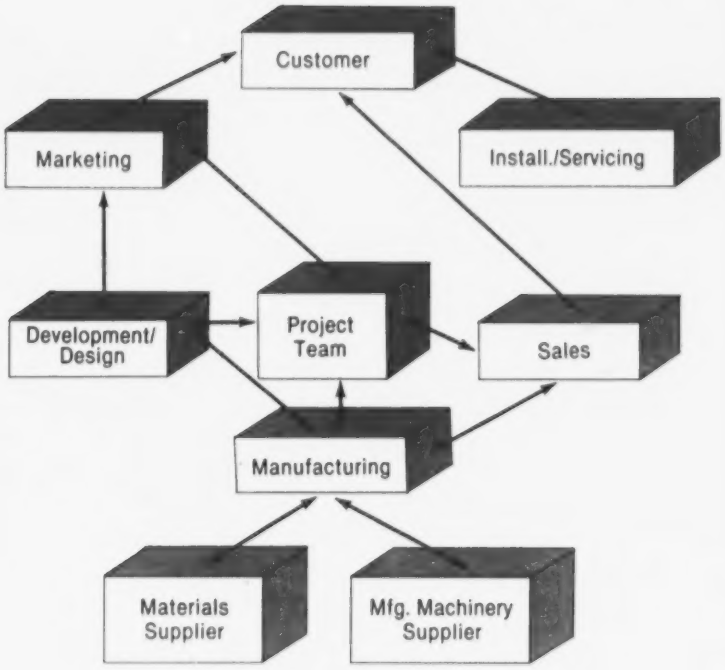
The effective exploitation of new technologies may be difficult, but it provides a major opportunity to excel in international commerce. It is incumbent on industry to join with other sectors of society in the effort to keep the United States in the forefront of the creation, development, and application of new science and technology. It is also imperative that government create an environment that facilitates the use of U.S.-created technologies by U.S.-based producers.

However, the opportunity for competitive advantage does not rest solely with the creation of new, even innovative, products or processes. The firm that is first to market with an innovative product or process must quickly focus on those tasks that will enable it to protect and enhance its market position. Once a new product or service is introduced, the challenge shifts quickly to improving its quality and reliability, adding new features, and reducing its cost by improving the production processes that are used.

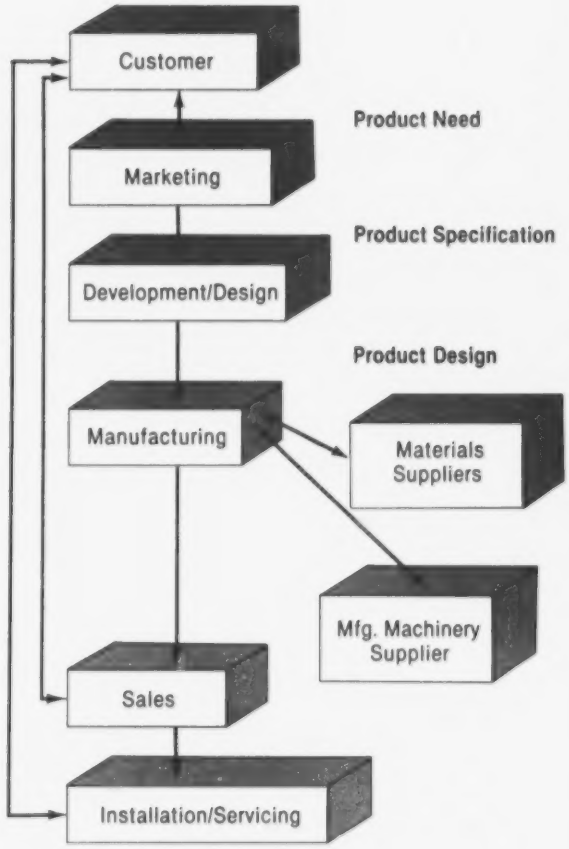
Process improvements that reduce material movement and part inventory, increase the yield of quality parts, or speed the response time of a service are real improvements in productivity. Increased performance in an existing product, as in the fuel economy of an automobile or aircraft, may be critical to maintaining competitiveness. Improved responsiveness to customer demands, whether in reducing delays or in providing more reliable information, can make a service activity more competitive. Only through **continuous improvement** can a company remain competitive.

Much of the success in achieving these improvements results from good engineering practice—the careful attention to function, processes, and materials—such that incremental improvements in quality and cost are realized more rapidly than is possible by potential competitors. The area in which U.S. industry has often lagged behind its competitors is in improvement of the manufacturing or service delivery system to improve quality and reliability and reduce cost.

Response To The Global Challenge



Product Realization Process



Traditional Organization and Procedures

The term "product realization process" denotes improved organizational arrangements and procedures to determine customer and market needs; translate these needs into designs suitable for manufacturing; produce a product that is introduced into the market; and make improvements that take advantage of better materials, processes, or equipment. The product realization process is interdepartmental and interactive. In contrast, traditional organization and procedures are compartmentalized and linear.

Response To The Global Challenge

To an increasing extent, in both the creation of new innovative products and services, and in the improvement of existing products or services, businesses have found it necessary to implement new ways of designing, developing, and manufacturing their products. **The critical initial step in improving performance is simply recognition of the importance of the production activity.** Some manufacturing firms recognize this by following the approach of **designing for manufacture** or **designing for assembly.**

An approach that recognizes that all elements of the organization must participate in creating an effective product is sometimes described as the ◄ **product realization process.** An integrated team effort, rather than the traditional compartmental and linear effort, is a critical element in this approach. The product realization process requires that disciplinary boundaries and other barriers to the effective exchange of information and people between functional groups in the organization be minimized. Employees at all levels should be engaged in the process of improvement through **employee involvement programs.**

The importance of these new approaches to the use and management of technology cannot be overstated. Although product performance and production efficiency are fully competitive for some U.S. manufacturers, the application of these new approaches is revitalizing U.S.-based production in a variety of industries. Many firms, including manufacturers of consumer products, manufacturers of capital equipment, suppliers of raw materials, commodity suppliers, and a variety of service industries, are experimenting with aspects of this new philosophy. The results are generally positive. There is a strong need to fashion these actions for each particular company, whether large or small, and to disseminate the lessons that are learned throughout U.S. industry.

Response To The Global Challenge

In sum, the globalization of production and of markets is a reality. To be competitive, U.S. industry must offer high-quality cost-effective products, processes, and services that possess a high perceived value. Accomplishing this goal will require many companies to develop operating procedures that

- encourage the full collaboration of all parts of the company from early concept throughout the product realization process;
- develop a strong sense of employee involvement; and
- commit the company to continuous improvement in all areas of operation.

As technology becomes an increasingly important competitive tool, the successful development and implementation of mutually supportive **technical and business strategies** will be critical to a company's performance. Increasingly, the **effective practice of engineering** is assuming a prominent role in many companies. The challenge for U.S. corporate management is to manage the enterprise effectively, to encourage the innovative capabilities of all of its employees, and to recognize the commercial opportunities that effective engineering offers.

To achieve these objectives, U.S. industry must commit itself to offering world-class products and services at competitive costs. The committee urges U.S. industry to embrace the concept of a *product realization process*, the importance of strong *employee involvement*, and a commitment to *continuous improvement* as key operating principles of each element of the enterprise.

The most effective means to these ends will vary from industry to industry, company to company, and market to market, but management techniques that closely link all of the elements of product design, fabrication, and service to the customer are broadly applicable to the competitive response of U.S. manufacturing and service industries.

Response To The Global Challenge

The Current Role of Government

Although industry brings products and services to the marketplace, government at the local, state, and federal levels has a pervasive influence on the environment in which industry operates. The federal role is most evident in fiscal and monetary policies, trade policies, regulatory actions, and controls that originate in legislative actions. The federal government supports a wide range of efforts in research and development and, through its procurement practices, develops and disseminates a wide variety of technical know-how, predominantly related to defense and the exploration and use of space.

At the state level, governments frequently take actions that support industrial development with the aim of generating employment and providing services. State and federal governments also share responsibility for the development and maintenance of critical elements of the public infrastructure, such as roads, airports, and waste disposal systems. To an increasing extent, state governments are encouraging their public colleges and universities to participate in programs that support new industries, improve productivity in local industry, and transfer new technology to industry.

Economic and Regulatory Policies

The government of every industrialized nation implements a large number of tax and regulatory policies which affect industries both within and outside the nation. If these policies had exactly symmetric impacts on all firms—both domestic and foreign—they would have few implications for competitiveness. It is the intrinsic nature of national economic and regulatory policies, however, that they do not equally affect all firms in all sectors in all countries. **It is important, therefore, that the U.S. government ensure that U.S.-based production and the innovative capacity associated with it not be needlessly disadvantaged in the global marketplace either by the policies of other nations or by U.S. domestic policies.**

The transnational economic impact of government policies is dramatically demonstrated for aircraft, where foreign government subsidies have enabled foreign manufacturers to undersell U.S. firms; for pharmaceuticals, where delays in authorizing the marketing of U.S.-developed products have weakened U.S. industry; and for telecommunications, where the rapid establishment of unique national industry standards by other nations has created barriers against the entry of U.S. products to particular national markets.

EXPORT CONTROL POLICY

Efforts by the United States since the late 1970s to enhance the effectiveness of national security export controls were necessary. . . . Nevertheless, U.S. control policies and procedures are in danger now of overcorrecting in that they fail to promote both military security and economic vitality. . . . The result is a complex and confusing control system that unnecessarily impedes U.S. high-technology exports to other countries of the Free World and directly affects relations with the CoCom allies.

Source: 12

Response To The Global Challenge

INTELLECTUAL PROPERTY PIRACY

The misappropriation of intellectual property—including the unauthorized use of proprietary manufacturing processes—costs American manufacturers between $8 and $20 billion per year, according to estimates by the International Trade Commission and the U.S. Chamber of Commerce. . . . Corning Glass Company, after investing over $200 million to develop its patented process for manufacturing optical fibers for telecommunications, was unable, under U.S. patent laws, to prevent Sumitomo Electric Industries of Japan from using this process without permission and selling its products in the U.S. market. . . . Nor could Corning collect royalties for the use of its patent.

Source: 13

The resolution of many of these issues must rest with effective action on the part of the federal government, which plays a crucial role in

- ☐ protecting intellectual property through international agreements;
- ☐ controlling technologically intensive exports;
- ☐ establishing equitable trade policies; and
- ☐ encouraging the mutual exchange of technical information across international boundaries.

In addition to dealing with the transnational effects of national policies, the government has a crucial role in the creation and implementation of domestic policies that encourage industrial innovation and stimulate domestic production. It is critical that policies encourage investment in R&D and in the capital improvements needed to increase productivity and efficiency.

Tax policy, antitrust regulations, tort and product liability laws, and regulatory policies related to the environment, health, and safety are domestic policy issues that also directly affect engineering and technology in industry.

Response To The Global Challenge

TAX POLICY ON RESEARCH & DEVELOPMENT

Treasury Regulation 1.861-8, first issued in 1977, requires that a portion of domestic R&D expenditures be allocated to foreign income. By thus increasing U.S. taxation, the regulation effectively increases the cost of performing R&D in the U.S. and encourages American companies to shift their R&D abroad. In response to concerns about the deleterious effects of such a shift on the competitive position of U.S. industry, the Congress has four times placed a moratorium on the application of this regulation. A permanent solution of this matter has not been achieved.

Source: 14

THE INCREASING TECHNOLOGICAL STRENGTH OF OTHER COUNTRIES

Many nations have developed centers of technological excellence, and the quantity of inventive activity outside the United States continues to grow. Newly industrializing areas such as South Korea, Taiwan, and Brazil are attaining higher levels of competence for technical development. Citations to Japanese articles in engineering and technology have doubled in the 1973-86 period. The total number of Japanese research publications surpassed the output of French and West German researchers in the 1970s, and the USSR in the early 1980s. In the mid-1980s . . . the number of Japanese technical publications will probably surpass the British total and be second only to that of the United States.

Source: 15

Response To The Global Challenge

Industrial innovation can be hampered by uncertainties about possible future product liabilities, weak protection of intellectual property, delay and uncertainty in implementing regulations, protracted regulatory approval processes, and government reimbursement or procurement policies that discriminate against innovative products. The number of months that various countries use to approve a new drug illustrates this point. ▶

Number of Months Required to Approve Drugs in Selected Countries (1980 and earlier)

Drug	United States	Canada	Norway	Sweden	Switzer-land	United Kingdom
Beclomethasone dipropionate	26	8	8	19	7	5
Sodium valproate	5	(a)	(b)	(a)	45	3
Cimetidine	13	8	19	20	10	2
Protirelin	28	(a)	(b)	21	9	(c)
Vidabrine	23	12	(b)	(c)	(c)	6
Somatotropin	15	(b)	(b)	23	10	8
Sodium iodide I-123	20	(d)				
Diazoxide	40	11	14	(a)	14	(c)
Phospho lipids	14	24	(b)	43	3	7
Amino acids	12	16	(b)	23	7	(c)
Danazol	30	16	17	34	21	6
Prazosin	40	30	27	(a)	10	6
Disophyramide phosphate	54	19	36	80	17	(c)
Propranolol:						
Arrhythmias	17	23	9	16	4	5
Angina	17	11	9	16	4	5
Hypertension	18	19	14	16	4	(c)

(a) Under review at agency at time of review.
(b) Not submitted to agency at time of review.
(c) Data not available.
(d) Not available in other countries.

Source: 16

Duration of U.S. Food and Drug Administraton Review Phase for New Drugs, 1985–1986

"The length of the . . . FDA review phase for the 46 NCEs ["new chemical entities"] (approved in 1985 and 1986) represent(s) no significant change from (the length of this phase) over the last ten years . . . The observed similarity of 1985–86 review times to those of previous years is striking, despite FDA efforts to streamline the review process and speed the introduction of new drugs."

Source: 17

Response To The Global Challenge

Antitrust policy, promulgated when the U.S. market was dominated by U.S. producers, has also affected industrial innovation. It has, however, been undergoing significant change. Several issues remain to be addressed, in particular, the prohibition of joint efforts in manufacturing process development.

Domestic policies must be responsive, however, to several other areas of national concern. We all share goals for a clean environment, safe products and workplaces, consumer protection, and a strong national defense. Progress toward the health, safety, and welfare of U.S. citizens is critical; but these goals cannot be reached unless we maintain vigorous economic growth and industrial competitiveness. In the interest of the nation's health, safety, and economic welfare, means must be sought to arrive at a more coherent and consistent formulation of regulatory policies in all the areas mentioned.

A better balance should be maintained between the impact of regulations or agency actions and the need to achieve economic competitiveness. This integrated view of the national welfare has not always prevailed in the past, as each agency has a tendency to focus on its own special mandate without adequate consideration of other national goals that lie outside its legislative mandate or mission.

■ **The dynamic nature of economic, political, and technological developments requires that government policies be constantly reviewed and adapted to ensure that they not only achieve the desired social, political, and national security purposes, but also support—or at least do not impair—our international competitiveness.**

ANTITRUST POLICY AND REGULATIONS

Antitrust policy strives, therefore, to keep markets competitive in order to promote innovation, and to encourage innovation in order to promote competition. . . . Joint research may even promote a competitive market as a whole by enabling the participants to provide new goods or services that would not have come into being except by the cooperative effort. . . . If the cost and risk of the research in relation to its potential rewards are such that the participants could not or would not have undertaken the project individually, the venture will have the effect of increasing rather than decreasing innovation. . . . Even when entry barriers [for new firms to the industry] are high, competitive incentives may nevertheless be maintained by the actual or potential competition from foreign firms or firms in a closely related industry, so that such joint research may not retard the pace of innovation.

Source: 18

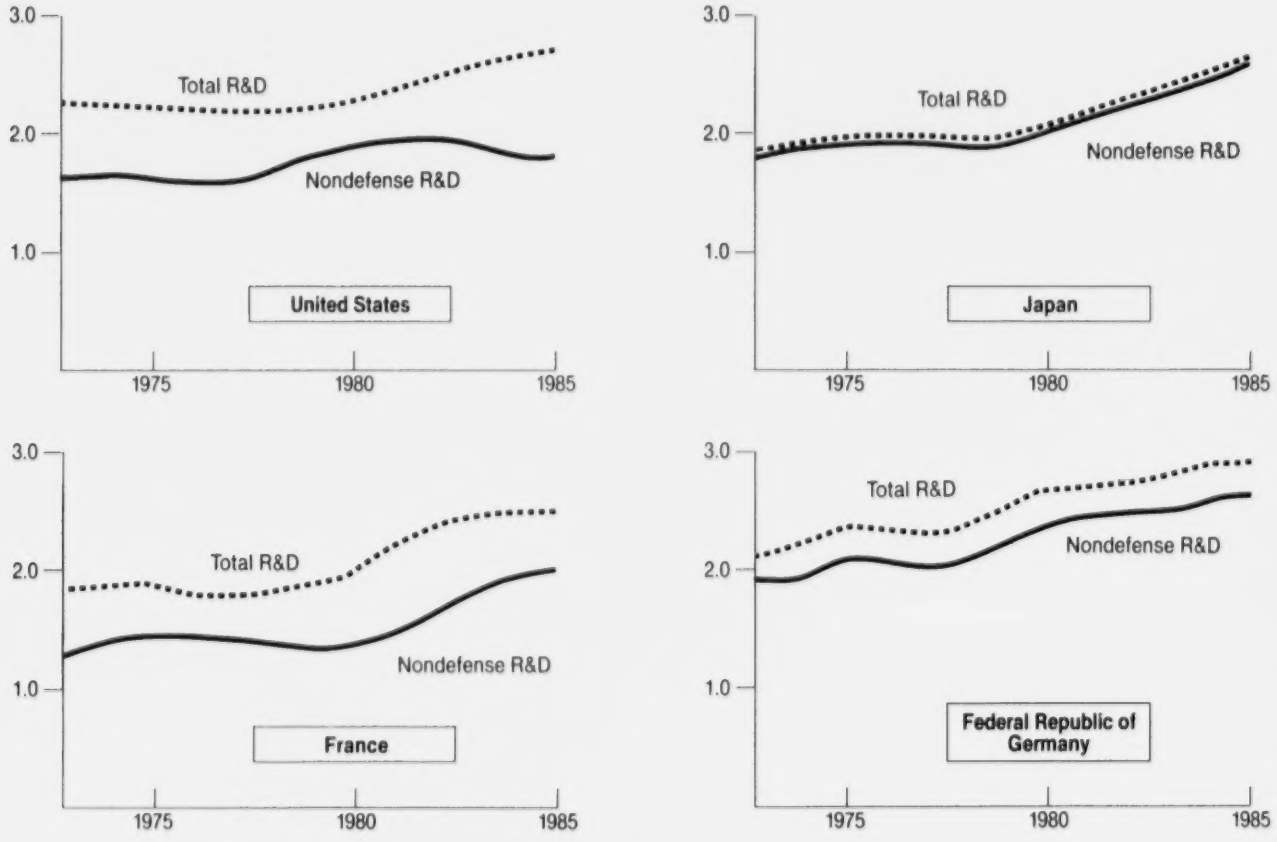
A joint research venture should be judged on the basis of its reasonableness, taking into account all relevant factors concerning competition, including but not limited to effects on competition, in properly defined, relevant research and development markets.

Source: 19

Response To The Global Challenge

Support of the R&D Enterprise

The R&D enterprise consists of a wide variety of activities located in industry, universities, government, and nonprofit organizations. The total national investment in R&D has been growing in both absolute dollars and as a percentage of GNP since the late 1970s and was estimated to reach about 2.8 percent of GNP in 1987. Although countries use different methods of measuring R&D and allocating expenditures to various categories, it is informative to compare general trends among the industrialized countries. Total R&D expenditures rose in Japan, France, and the Federal Republic of Germany from the late 1970s to 1987, similar to the trend in the United States. Whereas the United States has consistently spent a significant proportion of its GNP on R&D, the proportion of total U.S. R&D expenditures devoted to activities other than defense has been below that of Japan and the Federal Republic of Germany for many years.

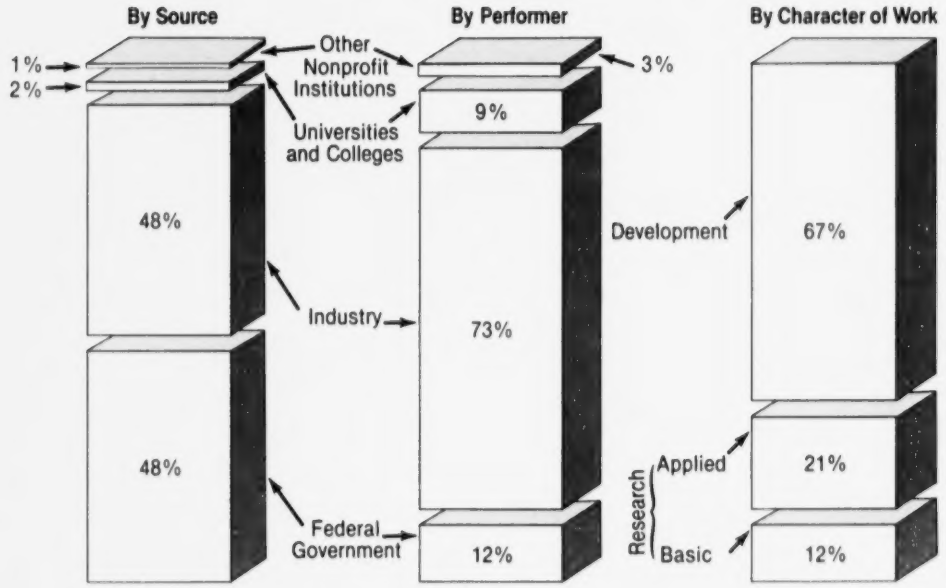


R&D as a percentage of GNP for the United States, Japan, France, and the Federal Republic of Germany, 1973-1985.

Source: 20

Response To The Global Challenge

Of the total national investment in R&D—approximately $125 billion in 1987—the federal government will provide about $60 billion. Only about $18 billion of the federal government's expenditures are not related to defense. Industry, universities and colleges, and the federal government perform about 73, 9, and 12 percent, respectively, of the national R&D effort. Of the total R&D effort, about 33 percent is devoted to research, 12 percent to the support of basic research, and 21 percent to applied research. With more than 50 percent of the basic research being done by the universities, it is important that appropriate facilities be available in the research universities to support their continuing role in research.



The national R&D effort. Estimated 1987 expenditures are $125.2 billion.

Source: 21

Response To The Global Challenge

Another element of the federal R&D program is the support of small business through the Small Business Innovation Development Act. This act required that all major federal agencies establish a Small Business Innovation Research (SBIR) program. This program provides that the R&D needs of each agency be advertised and that a minimum of 1.25 percent of the agency's external R&D funding be contracted with small businesses. Although the total funding has not been large—$400 million in 1987—industry response has been strong—15,000 proposals were submitted in 1987. Representative results suggest that the program has important potential benefits and supports the view that small businesses are significant sources of innovative products and processes.

EXAMPLES OF SMALL BUSINESS INNOVATION RESEARCH PROGRAM RESULTS

- ***Relational Technology, a software firm in California, had 6 employees in 1981 when it received its first SBIR award. It now has 450 employees. Its outside investment is $27 million and software product sales total $105M. One-third of this growth is attributable to the SBIR program.***

- ***NPI of Salt Lake City has had three promising biotechnology breakthroughs, which it ascribes mainly to SBIR research. The company has obtained $65 million in private investments from six large industrial firms, venture capital from five others, and has formed limited R&D partnerships with three major financial houses. Employment has increased from 40 in 1980 to 450 in 1987.***

- ***Flow Research, of Kent, Washington, currently working on a tactile sensor that senses force without the use of active electronic elements at the working array site, had 190 employees at the time of its first SBIR grant in 1981 and now has 810 in five spin-offs from the parent company.***

Source: 22

Response To The Global Challenge

The Changing Involvement of Government in R&D

Since the creation and production of new products, processes, and services are accomplished by industry, the federal government has traditionally assumed a major role in the development of technology only when it expects to be the principal purchaser of the output, as in defense or space exploration and use. With few exceptions, of which agriculture and clinical medicine are the most notable, the government has limited its involvement in technology development to providing support for the basic scientific and engineering research that undergirds the technology.

This historic role of government is changing rapidly. A number of events have occurred that indicate that the government is, on a selective basis, becoming more involved in stimulating and supporting the conversion of technology into commercial products and processes. As a result, government-industry-university relationships are undergoing rapid change. Furthermore, the government is redefining the role of its in-house laboratories in the support of technical developments in industry. This change in the relationship of the government, industry, and universities in matters related to the development and use of technology is having an important influence on all three sectors.

Federal Programs Encouraging University-Industry Interaction

Agency	Type of Action	Initial Date	Approx. Current Funding
National Science Foundation	Cooperative Research Centers	1973	$3 million (1987)
	Engineering Research Centers	1985	$30 million (1987)
	Science and Technology Centers	Proposed 1987	Proposed $30 million (1988)
Department of Defense	University Research Initiative	1985 (FY 1986)	$100 million (Combined FY 86 and 87)
Department of Energy	Various Cooperative National Laboratory University Programs	1985-86	Approx. $5 million (1987)
National Aeronautics and Space Administration	Centers for Commercial Development of Space	1985	$15 million (1987)
	University Space Engineering Centers	Proposed 1988	Proposed $4 million (1988)

In the support of university research, several new federal programs are encouraging a closer working relationship between industry and universities. This is particularly true for engineering research. The Engineering Research Center program of the National Science Foundation has been important in creating a focus for university-based engineering research that relates to industrial competitiveness. Industrial participation has influenced the content of the research programs and has stimulated the creation of several curricula involving manufacturing. An increased exchange of people between the universities and industry has resulted. Financial support for research has come both through equipment grants and through direct funding by industry. The impact of the various federal programs on the research and curricula of the universities has been substantial.

Response To The Global Challenge

Technological alliances among companies are also increasing. Faced with intense competition from overseas manufacturers, firms in some U.S. industries have joined together to form consortia, the purpose of which is to create, through jointly supported R&D, the next generation of technical developments that are critical to their business. In the semiconductor industry this response has taken the form of Sematech, a consortium that proposes to develop manufacturing technology for a new generation of integrated circuits. The U.S. machine tool industry is proposing a National Center for Manufacturing Sciences to explore new developments in discrete manufacturing.

Earlier efforts at joint industrial research include the Electric Power Research Institute (EPRI), the Gas Research Institute (GRI), the Council on Chemical Research, the Semiconductor Research Corporation (SRC), the Microelectronics and Computer Corporation (MCC), and the University Steel Resources Center. These activities are funded primarily by industry. Other industries are also considering the creation of consortia for the development of new technology.

The creation of these industry-wide consortia is not unique in the history of U.S. industrial research. Recent increased activity appears to stem from two causes. First, restrictions resulting from antitrust laws and regulations have been relaxed, allowing U.S. firms more latitude in joining together. Second, when the threat from overseas firms becomes sufficiently great, companies that are still fierce competitors for the U.S. market became more willing to join together to create a U.S. industry that is more competitive in the international marketplace.

Participation in consortia is not limited to industry. Government is also becoming involved, in that some of these consortia, for example, Sematech and the National Center for Manufacturing Sciences, have turned to federal and state government for partial funding. Sematech, in the first six years of operation, is currently projecting an expenditure of $1.26 billion, and the National Center for Manufacturing Sciences is projecting an expenditure of $30 million over three years. Industry is proposing to provide roughly half of these funds. The balance is being requested from government. Arrangements for government participation currently being explored include the possibility that funding will be provided by the Department of Defense for both of these efforts. The consequence of these actions, if funded, will be that the federal government assumes a much more explicit role in development activities closely related to commercial needs as a means of advancing industrial competitiveness.

Response To The Global Challenge

A second, very different form of federal involvement in the commercial sector is occurring through the Department of Defense. Having become concerned with the long-term viability of the U.S. industrial capability to support the nation's defense requirements in a national emergency, the department has launched a major program—the Department of Defense Industrial Base Initiative—to identify the needs for, and encourage the development of, critical manufacturing capabilities. Procurement policy will be a principal tool in accomplishing the objectives of this effort.

Finally, the government, through the Stevenson-Wydler Act (1980) and several successive legislative actions, has attempted to facilitate the transfer to industry of technology created in federally funded laboratories. The aim of this legislation is to increase the probability that pertinent technology developed in government laboratories will find more rapid deployment in industry.

THE FEDERAL LABORATORY CONSORTIUM FOR TECHNOLOGY TRANSFER

The Federal Technology Transfer Act of 1986 makes it easier for American companies to work with federal research and development laboratories to develop new or improved products, systems and services. The consortium was chartered by an Act of Congress to strengthen the cooperative transfer of federally developed technology to industry, state and local governments and universities.

The more than 600 federal laboratories and centers have annual in-house R&D budgets of approximately $20 billion and employ approximately 1/6 of the nation's science and engineering professionals.

Technology and expertise are available in virtually every area of science and engineering, including:

- ☐ ***manufacturing***
- ☐ ***transportation***
- ☐ ***advanced materials***
- ☐ ***ocean science***
- ☐ ***microelectronics***
- ☐ ***medicine***
- ☐ ***environmental protection***
- ☐ ***biotechnology***
- ☐ ***energy***
- ☐ ***communication***
- ☐ ***building and construction***
- ☐ ***computers and information***
- ☐ ***agriculture***
- ☐ ***superconductivity***

Source: 23

Response To The Global Challenge

These recent government actions can be characterized as follows:

☐ **Federal participation in the development of technology downstream from basic research has generally been considered only when the case has been made that a crisis exists, as when the semiconductor or machine tool industry was in danger of irreparable damage from overseas competition.**

☐ **Federal response has frequently been to turn to the Department of Defense, rather than a civilian agency such as the Department of Commerce, to act as the federal focus for justification and funding, even though the civilian sector may be the intended principal beneficiary of the program.**

Contrary to a widely accepted view, government has frequently assisted and participated with private industry in R&D activities of commercial importance. It has been involved in civilian industries such as agriculture and mining for more than 100 years, and it has long supported clinical experimentation. Government support of the National Advisory Committee for Aeronautics (NACA) was a strong force in developing a highly successful civilian aircraft industry, in the same way that early efforts by the Census Bureau were a force in developing the computer industry. The federal government has also extended assistance to the nuclear and electronics industries. One can properly view the recent actions of the federal government to become more active in R&D matters that relate to the competitiveness of industry as a logical extension of a pattern that has existed for decades.

Response To The Global Challenge

Factors Influencing the Future Role of Government in the R&D Process

A widely accepted view of the federal government's role in supporting technical developments downstream from basic research is that it should not actively support R&D activities that primarily benefit private industry. According to this view, the U.S. system should rely on the free market to provide the competitive incentives to improve efficiencies and create new innovative products, processes, and services. If a firm failed, it would be replaced by another. Employment lost by one firm would be balanced by employment growth in another. If a new innovative product was not created by a U.S. company at the first opportunity, another U.S. company might produce it at a later date. The success of the U.S. system has been derived from the encouragement that it provides for improved productivity and increased efficiency. Noncompetitive firms are not normally supported or protected.

These attributes of our system must be preserved, but we must recognize that the globalization of competition confronts this nation with a wholly new situation, one in which domestic market forces are often less important than market competition across national boundaries. Competition between U.S. and foreign manufacturers can lead to the disappearance of U.S. companies as the employment reappears overseas. A new product, process, or service that is not developed by a U.S. company or industry may be refined, produced, and marketed globally by an overseas competitor. In a rapidly expanding new product market, the loss of technological leadership can be difficult to recapture. For a mature technology, the opportunity to recapture leadership frequently requires that the production process be the focus, since product quality and cost often are paramount. In either case, recovery is difficult, often impossible.

In addition, the loss of leadership in critical fields may have a cumulative effect that not only strips the United States of technological know-how in these areas but may seriously deplete the overall capability of the United States to compete in several related fields.

Furthermore, many U.S. companies face a situation in which their foreign competitors are being encouraged to work together and are receiving assistance from their governments to exploit technologies that will improve their competitiveness. Although U.S.-based companies have traditionally sought to optimize their performance by individually satisfying the needs of their customers, stockholders, and employees, it should be recognized that the sum total of their actions may not provide an adequate solution for the global competitiveness problem of U.S.-based production.

In ensuring that the broad national needs of this country are satisfied, the federal government, in cooperation with industry, should concern itself with

- ☐ technological opportunities that transcend either the capabilities of a single company or industry;
- ☐ technological opportunities that are of such a nature that the benefits cannot be fully captured by the firm that makes the investment, and thus must be considered in the nature of a public good; and
- ☐ technological developments that have a social and economic impact on large segments of the U.S. population.

Although these arguments for government action are not new, the changing world economic and technological situation calls for a fresh assessment of possible selected responses by government that may go beyond the support for basic research.

Response To The Global Challenge

For the government to participate more actively in R&D directed at enhancing the health of the commercial sector, it must be prepared, both by its intent and through its processes, to be more supportive of programs important to technology with commercial potential, while relying on industry and the marketplace to identify the products and services that will be offered, both domestically and for export. Means must be developed to provide the government with more complete and systematic analyses of the industrial capability and enable the government to properly support, on a continuing and consistent basis, the technological developments that underpin the nation's industrial strength without simply replacing efforts that are properly the responsibility of industry.

Economic security must also be recognized as a national policy objective. The federal government must be continuously aware of the national importance of a commercially competitive industry. We can no longer afford a system that responds only to crises and considers military security the principal rationale for involving the federal government in the support of technical R&D.

In determining the scope of government activity in this area, it is necessary to consider the following issues:

- the role of the federal government in creating policies that stimulate industry to create new products and improve productivity;
- the role of the federal government in permitting and even supporting industry-wide consortia for the joint development of manufacturing or service delivery processes;
- the role of government in contributing directly to the early development of technologies ultimately intended for the commercial sector, as in the case of superconductors or advanced ceramics;
- the role of the government in encouraging universities to participate in ventures that advance science and technology important to the development of new products and processes with commercial potential;
- the role of state governments in encouraging improvement in the productivity and competitiveness of local industry; and
- the role of the federally supported laboratories in working with industry in the development of commercial products and processes.

An effective response by government to the global economic challenge requires that these issues be addressed in a comprehensive manner that includes careful assessment of the costs incurred in undertaking new actions and the impact that actions in one area might have on other activities. What is needed is the capability and willingness to look ahead and anticipate future circumstances rather than, as frequently occurs now, merely responding ad hoc to an immediate crisis—a response that frequently amounts to fighting yesterday's battles or mounting an action to limit damage to an industry. This change in outlook will be a significant challenge for the government since it must develop a mechanism that can, at the same time, both better anticipate change and respond in a timely way to the needs of a wide variety of citizens, businesses, and institutions.

Response To The Global Challenge

Actions by the Federal Government

If the government is to develop an expanded role in support of R&D related to industry and commerce, both government and industry must take steps to reduce the confrontational environment that has characterized their relations in recent years. Enhancement of such cooperative relations will require that government and industry work to develop a common view of technological and business trends and of technological directions to be taken in the national interest. Currently such consensus seems to be possible only when a crisis exists.

■ **This committee believes that mechanisms should be developed that encourage government and industry to work together more effectively to anticipate technological challenges, including the encouragement and creation of consensus within industry and between industry and government on technological factors and trends that affect both sectors.** Imaginative leadership will be required of both government and industry if this is to be accomplished successfully.

Before joint government-industry actions are undertaken, an important early step must be sound analyses of all aspects of the problem, including an understanding of the technological status of critical sectors of U.S. industry, the implications of emerging technologies for the health of engineering and technology in all sectors of U.S. industry, and deficiencies in the technological infrastructure of particular sectors. Since the analytic capability of this type that now exists in the government is limited and dispersed, a first priority should be to develop and mobilize this capability in a form that ensures the support and participation of the private sector in its studies. A small activity, perhaps located outside the structure of the government, staffed by highly qualified analysts who are keenly aware of industrial problems in detail, could be of great value.

With analyses of the type described above, the government would be better prepared to respond to industry initiatives. One form this involvement could take is to catalyze and in some instances support the formation of industry-wide research and development consortia to enhance the competitiveness of selected U.S. industries. This would require that the government be in a position to provide financial resources and that a process be developed to enable the government to share funding with industry-wide consortia if an industry group agrees to provide substantial private funds over the life of the project. In addition, the government needs to give greater attention to rapidly evolving sectors, such as services.

■ **If government is to develop an expanded role in support of R&D related to industry and commerce, it must rationalize its efforts and focus them in a consistent and logical fashion.**

□ **As a principal participant in achieving national competitiveness, the federal government must use its diverse capabilities to broadly encourage technological developments that are critical to sustaining the competitive interests of the nation. Efforts need to be focused through a designated entity that can effectively respond to industry initiatives and interact with nongovernment groups, including industry.**

□ **To carry out these responsibilities effectively, the government will require access to improved information and analyses. The federal government should, therefore, foster the creation of a supporting activity that, with private sector participation, could provide high-quality, in-depth analyses of the factors affecting the ability of civilian industrial sectors to compete in global markets.**

Response To The Global Challenge

These recommended actions are intended to supplement or augment those technical activities for which market incentives do not elicit a sufficient level of private investment, i.e., those activities that have a strong element of public good. They are predicated on the assumption that an improved cooperative relationship can be developed between government and industry. The relationship, however, must be such that government will not ultimately be in a position to impose its judgment on the marketplace in determining the products and services that should be offered by industry. The committee envisions a relationship that makes it possible to develop a variety of arrangements to improve industry's commitment to commercialize the worthwhile technology that has received government support as well as technologies that have been developed under other auspices. Arrangements that entail extensive cost sharing with industry are strongly encouraged.

Organizational changes proposed over the past several years in various studies would accomplish some of the objectives outlined above. This committee also examined a variety of alternatives by which its recommendations might be implemented. These included the possibility of assigning responsibility to a congressionally legislated office or agency, e.g., the Office of Science and Technology Policy, the Department of Commerce, or the National Science Foundation; the creation by Congress of a new executive agency or department, e.g., a Council on Industrial Competitiveness; or the creation of a quasi-independent activity that would be chartered by Congress and funded, at least in part, by the government.

Although the committee does not offer a specific recommendation for governmental action, it is firm in its belief that responsibility must be clearly assigned. It encourages further discussion among all interested parties so that this assignment of responsibility can be accomplished promptly.

The government, in framing its response, must be unusually sensitive to both the opportunities and the constraints within which any activity must operate if it is to maintain the support and cooperation of industry. To foster the proper long-term relationship with industry, the industrial community should play an important part in the planning and creation of the structure.

Finally, the committee recognizes that the allocation of federal funds may be influenced by special interests with justifications that bear little relation to the stated purpose for expenditure. Because such actions can lead to efforts that are not effective in advancing U.S. competitiveness, this committee urges that any entity designated to implement this recommendation be insulated as much as possible from such counterproductive influences.

Response To The Global Challenge

Actions by State Governments

Businesses large and small are affected by state taxes, regulations, and policies. In many ways, the impact of state government activities on business can be similar to that of the federal government; state governments play a significant role in supporting a strong science and technology infrastructure and must avoid policies that discourage economic development. The states, however, have unique capabilities and attitudes that are not easily duplicated at the federal level. It is these that the committee emphasizes here.

☐ State governments are generally more aware of, and responsive to, the needs of local industry. They can, therefore, interact more effectively with small business.

☐ As history shows, the states can experiment with innovative programs more readily than the federal government can, for example, with technological extension programs.

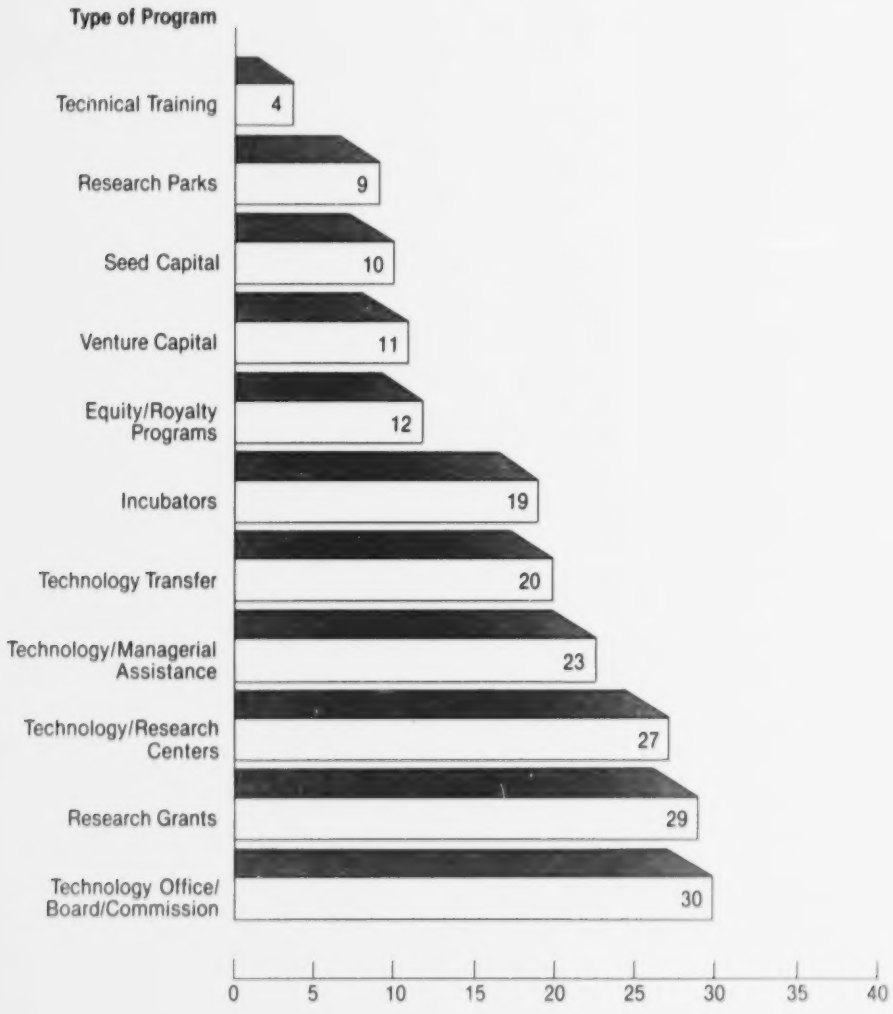
☐ States can join together to generate programs that will benefit an entire region.

☐ State governments are actively involved in supporting the education system, through offices that assist and oversee the primary and secondary school system, through support of universities, colleges, and vocational institutes, and through the encouragement of continuing education programs. *(See pages 55 through 67 for discussion of the development of the work force.)*

State government support of technological development is increasing both in the level of financial commitment and in the types and character of programs supported. The objective of many of these programs is to improve the capability of local industry and to create jobs through encouraging business development—often businesses engaged in the development and application of new technology. Not only are the states better able to interact with and understand the problems of local industry; they are the principal supporters of a university system that generates new technologies and educates the work force. With these resources, and with the incentive to create local employment, they can encourage the conversion of technologies into new products and services, assist in the creation of new businesses, and work to improve the productive capability of existing organizations.

A unique opportunity exists for states to support small businesses, many of which have special problems in keeping abreast of new technical developments and translating these developments into products or processes that benefit their companies. As suppliers of products or services to larger companies, or as providers of a product or a service that may be displaced by a foreign company, small companies must be encouraged to make continuous improvements in their productivity and to use the best available technology in maintaining their competitiveness. In many states, economic development agencies have been established and are effectively positioned to continue to assist small businesses in achieving increased productivity through application of new technology.

Response To The Global Challenge



Number of states supporting technology initiatives, FY 1986; (program expenditures total $700 million).

Source: 24

Response To The Global Challenge

State initiatives are numerous and diverse, as evidenced by the number of states supporting a variety of research programs, most of which are chosen for their potential to encourage economic development. Because many of these research programs are carried out at state-supported institutions of higher learning, the state government contribution to research is often much larger than the budgets contained in specific economic development projects. In 1986 the states earmarked about $700 million for technology-oriented initiatives. Nearly 40 percent of these funds supported technology and research centers, 23 percent were used for new ventures and to provide capital to small companies, and 18 percent went for research grants.

◄

Because many of these programs are in an early stage of development, it is premature to attempt a comprehensive assessment of their combined impact on state economic development. It is generally agreed, however, that the state programs are contributing in an important way to an improved competitive environment.

■ **State governments should**

☐ **strengthen and expand their local industrial base through the development and dissemination of technology and know-how that can be effectively used by small businesses to improve their productivity,**

☐ **continue to support the initiation of high-tech small businesses,**

☐ **strive to create a favorable environment for U.S.-based businesses, and**

☐ **seek to improve the quality of the education system within their boundaries.**

Those states without a centralized activity should evaluate the merits of an industrial extension system that would coordinate statewide efforts and provide a central location for scientific and technical information. Recognizing that many of the current programs are new and, in some sense, experimental, the states should regularly review and evaluate these programs to determine the most effective means of expanding their impact. Programs that prove successful should be sustained, expanded, and continuously improved. States should also continuously review their tax structure, laws, and regulations to ensure that they do not place undue burdens on businesses, large and small, operating within their boundaries.

Response To The Global Challenge

BENEFITS OF INDUSTRY- UNIVERSITY ALLIANCES

TO UNIVERSITIES

- ☐ *Generates Income*
- ☐ *Helps attract and retain faculty*
- ☐ *Provides opportunity for extended contact and mutual evaluation by student and potential industrial employer*
- ☐ *Fulfills a social duty to help translate ideas into useful products and services*

TO INDUSTRY

- ☐ *Gives access to advanced ideas in science and technology*
- ☐ *Provides contact and consultation with research leaders*
- ☐ *Attracts students to company-related research and development*
- ☐ *Gives access to specialized university developments*
- ☐ *Provides share in patentable developments*

University-industry alliances have adopted a variety of patterns: nonprofit foundations, for-profit corporations and joint ventures, wholly owned subsidiaries, individual company cooperative research arrangements with a single university, multiple industry support of research at a single university, nonprofit industry, consortia supporting research at several universities, and university centers with state or federal participation.

Response To The Global Challenge

The Role of the Universities

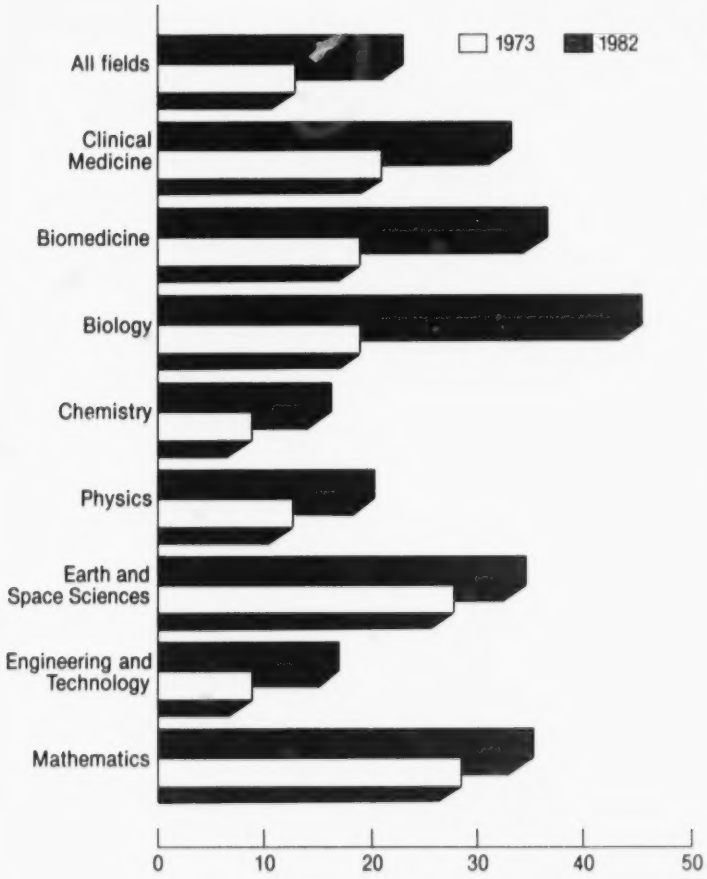
Universities, through their research programs, have been major contributors to the basic science and engineering that underlies much of industrial technology. They have recently assumed a more active role in the translation of that understanding into technology and the application of that technology to solve problems important to industry.

The stimulus for this change has come primarily from two sources:

- a desire on the part of federal agencies to promote the efficiency of translating research results into products, processes, and services; and
- efforts of universities to work more closely with industry and thereby encourage industrial support of university research programs.

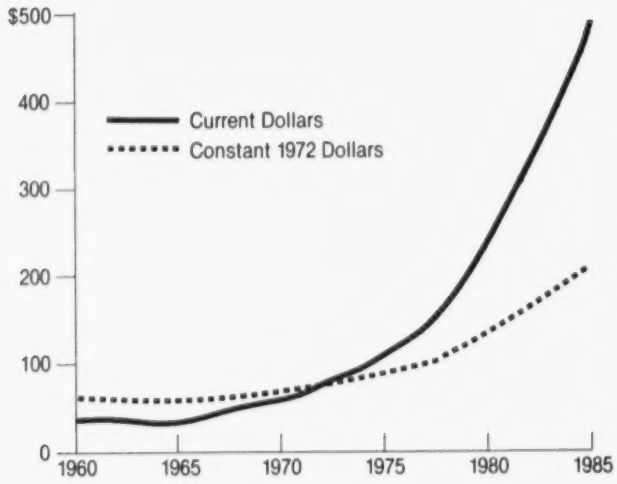
These actions have prompted many universities to undertake programs directly concerned with technologies that may have commercial potential. A principal focus of many of these efforts is the creation of a variety of new alliances between industry and the universities. There are many potential benefits of such alliances. Two measures of the success in achieving these benefits are a greatly expanded investment in university-based R&D by industry and an increased collaboration between university and industry research personnel. The latter is seen in the increasing number of publications that are coauthored by engineers and scientists from industry and academe. Many universities are attempting to derive revenue directly from technical developments carried out in their research laboratories, through licensing of patents, the sale of know-how, and the encouragement of new entrepreneurial businesses that are associated with the universities. Some universities are broadening their extension services to include an industrial program, with particular effort being made to assist small businesses in their efforts to improve productivity.

University-Industry Cooperation in Science and Technology



Percent of publications coauthored by engineers and scientists from industry and academe.

Source: 25



Industry expenditures for R&D in colleges and universities, in millions of dollars.

Source: 25

Response To The Global Challenge

Actions by the Universities

Changes in the relationship between universities and industry, and the increasing involvement of universities in commercial enterprises and in economic development, are creating important new policy issues for universities. These issues include the manner in which proprietary information is treated, the sharing of rights to intellectual property created in university laboratories, the proper role for the universities in the creation of new companies, and the increasing number of faculty members with outside commercial interests. These developments have been generally beneficial, leading to increased interactions between industry and the university personnel, a new source of revenue for the universities, and encouragement of faculty and students to be aware of potential commercial applications of their research.

Although there is little cause for concern about recent practices or the results of these practices, it is important that the broad implications of these changes be understood, appreciated, and continuously monitored by the universities themselves. The long-term health of the university research system is of such great importance to the technical enterprise of this country that every effort must be made to explore the implications of new arrangements before problems arise.

■ **These implications can best be explored by undertaking a study of**

☐ **how U.S. colleges and universities are affected by their activities in various aspects of the commercialization of products and processes and**

☐ **the means by which technical understanding and developments are transferred to industry.**

The objective of this study should be the exploration of various means for

☐ improving the capability of the university to participate in R&D important to industry; and

☐ enhancing the effectiveness by which the results are transferred to industry.

The challenge, of course, is ensuring that this involvement does not compromise the primary functions of universities in research and teaching or lead to a reduction in the open communication of academic research. This national evaluation should be of particular value to university administrators who are examining the opportunities and needs for working more effectively with the commercial sector.

Noting that some aspects of these issues have been examined in recent studies, this committee urges that the study concentrate on those aspects of university-industry relations that have the potential to affect universities adversely. Duplication of earlier efforts should be avoided. Various groups, including the White House Science Council, the National Science Board, the American Association of Universities, or the Government-University-Industry Research Roundtable, could appropriately sponsor or conduct such a study.

Developing A Competitive Work Force

4

Education is a social process, perhaps the most important process in determining the future of our country; it should command a far larger portion of our national income than it does today.

James B. Conant

Maintenance of our national competitiveness requires a literate and broadly trained work force that can respond to increasingly rapid changes in the workplace. The responsibility for ensuring that our populace is prepared for this changing work environment is shared by all elements of our society—the family, the general public, the employer, the individual, professional societies, and the education system. Furthermore, both young and old, labor and management, government and industry must recognize that a rapidly changing world demands that the educational experience not cease with the completion of a particular level of formal education. Central aspects of a successful career are a commitment to continuous learning and inquiry about the unknown as well as a realization that learning and personal development are lifelong processes.

Encouraging and supporting these personal characteristics is a critical element in the development of an adaptive and effective work force. Achieving a literate work force that is committed to continuously upgrading its capabilities will require significant efforts. **This nation must place a high priority on improving its education system and must commit itself to making the investments that will be required to achieve this goal. Quality in education is every bit as important to the United States as is quality in products, services, or government.**

America's ability to compete in world markets is eroding. . . . As in past economic and social crises, Americans turn to education. They rightly demand an improved supply of young people with the knowledge . . . and skills to make the nation once again fully competitive.

Source: 26

Developing A Competitive Work Force

The educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a nation and as a people. Our once unchallenged preeminence in commerce, science, and technological innovation is being overtaken by competitors throughout the world.

Source: 27

Actions Related to Primary and Secondary Education

To be illiterate in a technologically dependent society is to be trapped. Literacy is a condition for entry into most positions in the manufacturing and service sectors. Advancement and upward mobility depend increasingly on skills gained in primary and secondary education. Moreover, the evidence is clear that a worker without the basic skills in reading, writing, and arithmetic requires a longer period to find a new position after a dislocation in employment than does a worker with those skills.

None of these factors is likely to change significantly in the near future. Predictions of the changing occupational structure suggest that many of the job categories that exist today will grow by the year 2000. Although some projections suggest that the number of positions that can be filled by either unskilled or semiskilled people will decrease in the future, there is no consensus on this point. There is little reason to believe, however, that the importance of literacy to the employee or to the employer will be less in the future than it is today. **If we are to remain competitive, our work force must receive training that is equal to or better than that received by the work forces of nations that are our strongest competitors. This must become our national goal.**

Developing A Competitive Work Force

The Changing Occupational Structure, 1984–2000

Occupation	Current Jobs (000s)	New Jobs (000s)	Rate of Growth (Percentage)
Total	**105,008**	**25,952**	**25**
Service Occupations	16,059	5,957	37
Managerial and Management-Related	10,893	4,280	39
Marketing and Sales	10,656	4,150	39
Administrative Support	18,483	3,620	20
Technicians	3,146	1,389	44
Health Diagnosing and Treating Occupations	2,478	1,384	53
Teachers, Librarians, and Counselors	4,437	1,381	31
Mechanics, Installers, and Repairers	4,264	966	23
Transportation and Heavy Equipment Operators	4,604	752	16
Engineers, Architects, and Surveyors	1,447	600	41
Construction Trades	3,127	595	19
Natural, Computer, and Mathematical Scientists	647	442	68
Writers, Artists, Entertainers, and Athletes	1,092	425	39
Other Professionals and Paraprofessionals	825	355	43
Lawyers and Judges	457	326	71
Social, Recreational, and Religious Workers	759	235	31
Helpers and Laborers	4,168	205	5
Social Scientists	173	70	40
Precision Production Workers	2,790	61	2
Plant and System Workers	275	36	13
Blue Collar Supervisors	1,442	-6	0
Miners	175	-28	-16
Hand Workers, Assemblers, and Fabricators	2,604	-179	-7
Machine Setters, Operators, and Tenders	5,527	-448	-8
Agriculture, Forestry, and Fisheries	4,480	-538	-12

Source: 28

Many recent studies have analyzed and presented recommendations for increasing the general literacy of the work force of the United States. They all focus on the **need for a national strategy that will intensify current efforts to improve public education at primary and secondary levels. A key ingredient in accomplishing this goal is the establishment of firm and realistic objectives to guide continuous improvement of school programs. Clear measures must be identified for determining progress against these objectives.**

Developing A Competitive Work Force

Objectives for achieving continuous improvement should be established in each of the following areas:

☐ the capability and qualification of the teachers in the subjects they teach;

☐ the level of performance of students in the basic skills of reading, writing, and arithmetic;

☐ the fraction of students that complete grade 12, particularly for minorities and disadvantaged youth;

☐ the recognition and encouragement given to the exceptional student with unusual capabilities or skills;

☐ the treatment of mathematics, science, and technology in the curriculum; and

☐ the number of qualified students who receive encouragement and ultimately choose to obtain college and university training in science and engineering.

The future supply of engineers and scientists is determined in no small way by the early general training that students receive. The successful completion of early courses in mathematics and science and the encouragement for students to continue with a career in science or engineering are critical elements affecting career choices. To enhance the opportunities and interest of students in pursuing a career in science and engineering, primary and secondary school systems should establish objectives for

☐ improving the quality of mathematics and science programs; and

☐ developing opportunities for students to understand more completely the nature of a technical career.

In accomplishing the objectives listed above, the nation must recognize the intense competition that exists from other sectors for the skills that good teachers of science and mathematics possess. If the best-qualified teachers are to be retained in the school systems, increased effort must be made to provide salaries and benefits that are competitive with other sources of employment. In addition, it is important that the working conditions for teachers be improved so that they experience increased professional recognition and opportunity for professional development.

Although the primary and secondary schools depend on strong popular support as they strive to provide a sound basic education, ways must also be found to motivate individual students and their families. Ways must be found to attract back into the education system the student who has dropped out or been excluded. Scientists and engineers can contribute by participating more actively in working to improve the education programs of local schools. Interested individuals who have experience in technical fields can significantly encourage minorities to continue in school, increase the attention given to potential science and engineering students, and support specially talented students.

Developing A Competitive Work Force

Actions Related to Higher Education

The U.S. system of higher education ranks among the best in the world in providing both undergraduate and graduate students with an enriching experience in education. The diversity of academic programs and the variety of institutions, many with special areas of emphasis, have provided a system that is the envy of most other nations. Engineering education enjoys the benefits of this diversity through both the various courses offered and the variety of research opportunities available.

The goals for undergraduate engineering education, while varying among schools, are generally contained in those currently under discussion at the Massachusetts Institute of Technology. These goals, as stated by Jack L. Kerrebrock, MIT, are "first, that engineering undergraduates should have begun to understand the diverse history of human societies as well as their literary, philosophical, and artistic traditions; and second, that these students should have begun to understand and respect the economic, managerial, political, social, and environmental issues surrounding technical developments."

Achievement of these goals requires that the system of higher education be capable of responding to new opportunities in course content and research and that it continue to attract the best students to its programs.

New Programs

The recognition that many technical areas are increasing in importance to industry, and the growing interest of students in exploring areas that relate to the needs of industry, have encouraged many colleges and universities to experiment with new ways of offering students an opportunity to study and to develop special skills. The recent emergence of programs focused on manufacturing is an important example of this phenomenon. Although manufacturing engineering has not been a traditional area of academic concentration in recent years, this has changed with the increasing emphasis on competitiveness and the evolving opportunities to expand the technologies used in manufacturing.

EXAMPLES OF 1986 ACCREDITED PROGRAMS IN MANUFACTURING ENGINEERING AND TECHNOLOGY

MANUFACTURING ENGINEERING

Master's degree

University of Massachusetts
Oregon State University

Bachelor's degree

Boston University
Utah State University

ENGINEERING TECHNOLOGY

Bachelor's degree

Manufacturing engineering technology

Arizona State University
Milwaukee School of Engineering
New Jersey Institute of Technology
Brigham Young University
Rochester Institute of Technology
University of Nebraska at Omaha
Oregon Institute of Technology

Manufacturing processes

California Polytechnic State University

Manufacturing technology

Oklahoma State University
Indiana Purdue at Fort Wayne
Memphis State University
University of Houston

Source: 29

Developing A Competitive Work Force

New research programs and organizations are focusing on a number of technologies of importance to competitiveness. Examples of these are the Engineering Research Centers, sponsored by the National Science Foundation and located at universities throughout the country. Several other industrially oriented academic centers, including many state-sponsored university-industry technology programs, are in active operation. The fields of engineering research being pursued in these centers cover a wide range, including the design, fabrication, and application of microelectronics for intelligent manufacturing systems; submicron structures; biotechnology; composites manufacturing science and engineering; "near-net-shape" manufacture of discrete component parts; combustion; telecommunications; steel processing; interactive graphics; and large-scale structural design. Many of these activities have proved attractive for both graduate and undergraduate students. These programs have also increased the opportunities for enhanced interaction with industry.

Additional opportunities exist for developing new curricula oriented toward exploring the entire commercialization process in industry—the product realization process. Other opportunities exist for developing curricula and research programs that are oriented toward the particular technological needs of service industries, curricula that expand the understanding of the R&D process and the management of technology, and continuing education courses for practicing engineers and scientists.

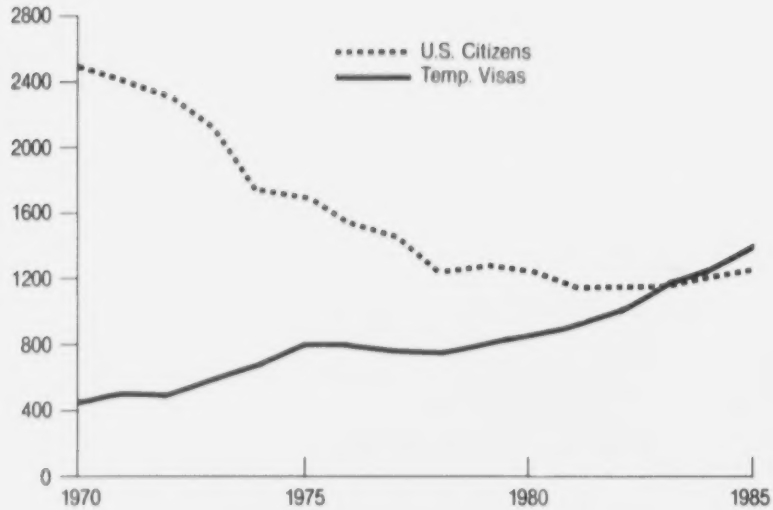
This committee encourages universities to expand existing programs and to develop additional courses and research programs that relate directly to the technologies important to U.S. competitiveness. **Resources need to be provided to colleges and universities to encourage experimentation and establishment of new programs and curricula that will lead to improved industrial competitiveness. Government and industry must share in providing the necessary resources.**

Developing A Competitive Work Force

Student Demographics

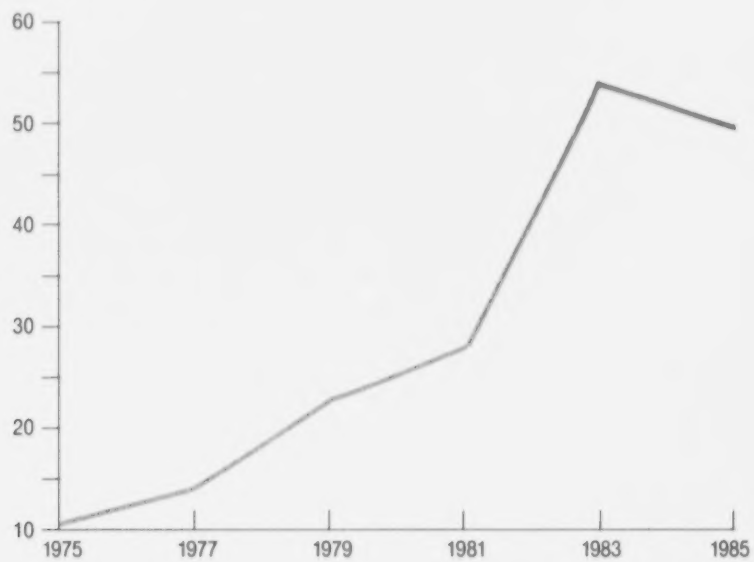
One measure of the high regard in which our system of higher education is held is the large number of foreign nationals that come to this country to study and to do research. This mixture of people of many backgrounds enriches the educational experience for all participants. There is, however, concern both with the high fraction of foreign-national students in U.S. graduate engineering programs and with the number of foreign-born faculty members in entry-level positions in engineering schools—more than 50 percent in 1985.

A more serious concern is the small and declining proportion of U.S. citizens who are studying for advanced degrees in engineering. The number of doctoral degrees awarded to foreign engineers has nearly doubled between 1960 and 1984.



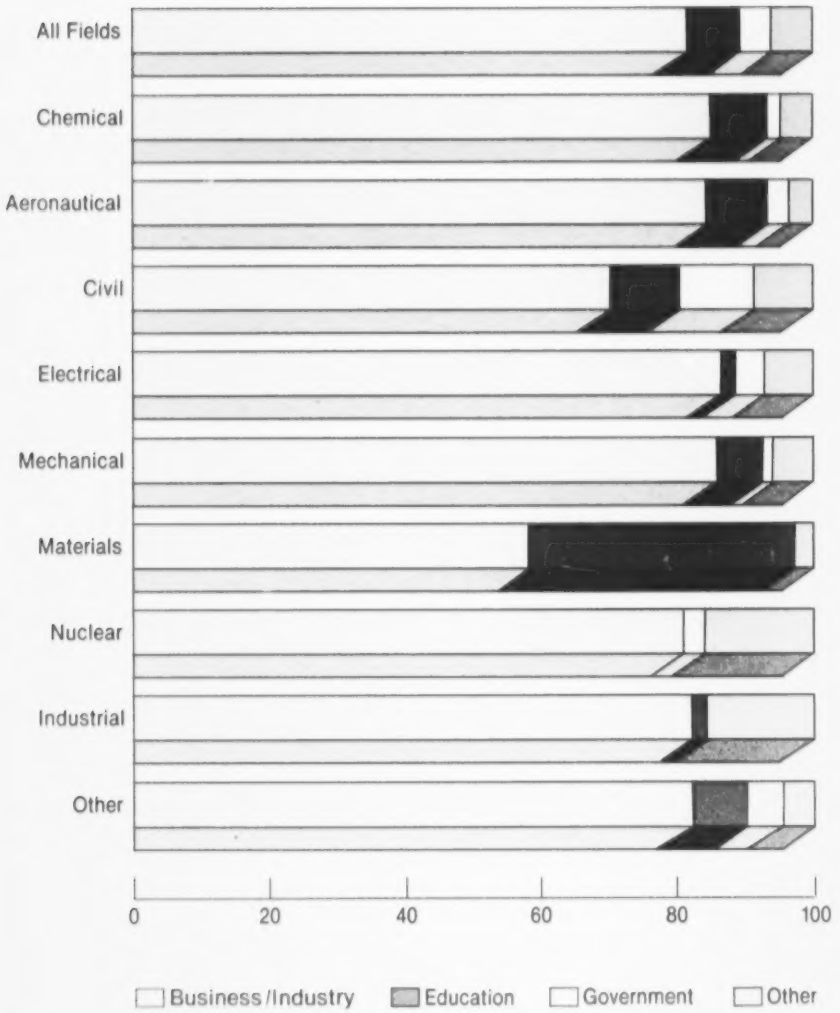
Engineering doctorates awarded to U.S. citizens and to holders of temporary visas, 1970–1985.

Source: 30



Foreign-born engineers as a percentage of all U.S. engineering assistant professors, age 35 or less, 1975–1985.

Source: 30



Percent of foreign engineers by sector of employment, 1982.
NOTE: Includes only individuals reporting employment in engineering occupations in 1982.

Source: 30

Developing A Competitive Work Force

Not only are fewer U.S.-born students entering the technical labor force, but present immigration laws limit the opportunities for U.S. firms to employ the foreign nationals who have been trained and have graduated from U.S. colleges and universities. About 23 percent of foreign engineering graduates who received a B.S. degree and 18 percent of those receiving an M.S. degree during the 1982/1983 academic year were employed in the United States in 1984. Nearly 40 percent of the 1985 foreign graduates with temporary visas indicated that they planned to seek immediate employment in the United States, and more than half of the foreign engineers employed in this country work for business and industry. Also, if historical trends persist, many of those who initially find employment overseas will later return to the United States.

The general conclusion that can be drawn from these statistics, however, is that a significant fraction of the foreign-born technical professionals who were trained in this country are not immediately employed here. Both problems—the dearth of U.S.-born students with advanced degrees in engineering and the difficulty of retaining foreign-born engineers educated in the United States—need to be addressed.

■ **The federal government should develop an incentive program to encourage more U.S. citizens to continue to pursue advanced technical degrees in fields that are increasingly dominated by non-U.S. citizens.**

Such incentives could include augmentation of graduate student stipends, tax advantages for individuals pursuing graduate study in a technical field, a substantial increase in the number of national fellowships for students in technical fields, and incentives to industry to sponsor graduate technical education for working engineers and scientists.

■ **Additionally, consideration should be given to modifying existing laws and regulations that prevent retention of U.S.-educated foreign nationals with advanced degrees in science and engineering.** These scientists and engineers represent a valuable human resource that should be available to U.S. employers.

Developing A Competitive Work Force

Actions Related to Continuing Education

It has become increasingly clear that lifelong learning is critical if our citizens are to cope effectively with the complexities and rapid changes of modern society. Without it, they will be less able to take advantage of the many opportunities that our system offers. Technological obsolescence can reduce the effectiveness of people at all levels—the engineer, the manager, or the worker on the line. New entrants to the work force will need an update in their technical knowledge base in three to seven years. Because at least three-quarters of today's work force will still be working in the year 2000, it is clear that career-long education and training are an urgent need.

The substantial benefits of continuing education are shown by data gathered on more than 1 million experienced workers (those with at least three years' tenure in their jobs) displaced in 1979-1983; workers with higher levels of training in job-related skills experienced shorter periods of unemployment and found better-paying jobs than their less-skilled colleagues.

The annual cost of the total learning enterprise (all public and private expenditure on elementary, secondary, and postsecondary education; informal and formal employee training; and government training for civilians) is estimated to have been over $450 billion in 1985. Nearly half of this amount was spent for formal and informal employee training. In 1987 more than 23 million people were enrolled in some form of adult education. Of this number, nearly 20 million were in the labor force, either currently employed or seeking reemployment.

Developing A Competitive Work Force

Adult Education Activity in the United States

Reasons for study (1984)[1]	Number of courses taken (000's)	Percentage of total courses taken
To get new job	4,803	12
To advance in current job	19,702	48
Other job related	1,656	4
Not job related	14,590	36
Total courses taken	40,751	100

Provider of instruction (1981)[2]	Percentage of total courses provided
School (High; trade & vocational; 2 & 4 yr. colleges; universities)	53.9
Business or industry	13.7
Private community organization	8.5
Labor or professional organization	5.0
Government agency	7.8
Other	11.1
Total	100*

*24.8 percent of all courses were provided by employers.

[1]Source: 31

[2]Source: 32

Engineers can be productive . . . over a longer period, thus increasing the size and effectiveness of the engineering work force, if they have access to effective continuing education. Needs of engineers for lifelong maintenance of competence through continuing education are met by a variety of means, including employers, professional/technical societies, academic institutions, private vendors, on-the-job learning, and the individual initiative of the engineer. The various providers of continuing education should keep these educational sources available to the practicing engineer . . . should expand their offerings . . . and should recognize the value of continuing education in improving the effectiveness and adaptability of their engineering employees.

Source: 33

Developing A Competitive Work Force

INSTITUTIONAL AND INDIVIDUAL COMMITMENT TO LIFELONG EDUCATION SHOULD BE ENCOURAGED AND STRENGTHENED

The primary responsibility to undertake such education lies with the individual. However, industry and government must recognize the importance of continuing education and place a high priority on providing opportunities and support for work force participation. . . . Continuing education is particularly important for the technical work force which must keep abreast of rapidly changing technology. Coupled with retraining, continuing education also plays a vital role in easing displaced workers into new careers.

Source: 34

Once a worker has been hired, the most important source of skill-improvement training is the employer. The dominant role of employers in funding and providing career training strongly influences who receives training. College graduates are twice as likely to receive such training, whereas those with less than a high school education are only one-fourth as likely to receive career training. Other differences arise because employees in larger firms receive more training than employees in smaller firms, and employer-provided training is greater in technologically dynamic industries than in others.

Career-long educational needs of the work force are extraordinarily diverse and the special demands of career-long education are not entirely congruent with the methods and tempo of the established academic system. Also, education is obviously not the primary goal of most businesses. As a consequence, career-long education is not practiced as widely as it needs to be to cope with technological change and to enhance national productivity.

Developing A Competitive Work Force

Where investments have been made in career-long education, a variety of training systems have arisen, from short special lectures to full courses giving academic credit. Many of these education programs are excellent and merit wider dissemination and use.

The federal government involvement in continuing education has been largely indirect. Recent changes in the tax law now make employer-provided tuition taxable income for the employee. This change creates an additional disincentive for continuing education.

The economic competitiveness of this nation is intimately tied to a work force capable of using modern tools and technology. Because career-long education is an increasingly important element in maintaining the viability of the work force, a major challenge is to ensure that American industry creates an environment that will stimulate personal career development and intellectual growth.

■ **The long-range needs for a capable and adaptive work force require that continuing education become an integral part of the career development of each individual, particularly of every scientist and engineer. Industry, government, the professional societies, and the educational institutions share the responsibility for creating a system that will be of high quality and will encourage the employee and the employer to invest in obtaining skills of future value both to the individual and to industry.**

THE IMPORTANCE OF CONTINUING EDUCATION

Continuing education is an entity in itself and can no longer be viewed as an "add-on" role of industry or academia . . . . Continuing education . . . is essential to increasing national productivity.

Source: 35

5 Coda

The conclusions and recommendations in this report reflect the committee's concerns with maintaining U.S. competitiveness. The committee is hopeful that readers will recognize and endorse a pervading theme of the report—the concept of continuous improvement. The same logic that applies to production processes—that opportunities always exist to improve the performance of the system—applies to the activities of government, industry, academia, and other institutions. In production environments long-term performance depends on a commitment to make all elements of the system more efficient—to produce high quality and quantity using fewer resources. Long-term U.S. performance depends ultimately on the same constant concern with improving the performance, quality, and efficiency of all of our institutions. The reasoning, conclusions, and recommendations in this report reflect the committee's understanding of continuous improvement in production and the committee's belief that the concept has much to offer in nonproduction environments.

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